FOURTH INTERNATIONAL CONFERENCE ON PALEOCEANOGRAPHY

ICP IV

SHORT- AND LONG-TERM GLOBAL CHANGE: RECORDS AND MODELLING

21–25 SEPTEMBER 1992
KIEL/GERMANY

PROGRAM & ABSTRACTS

ICP IV - Overview

WORKSHOPS

Thursday, Sept. 17 - Saturday, Sept. 19 : Carbon Cycling in the Glacial Ocean: Constraints on the Ocean's Role in Global Change (NATO ARW) *(R. Zahn, M. Kaminski, L. Labeyrie, T. Pedersen)*

Saturday/Sunday, Sept. 19/20 : Taxonomy of Quaternary Planktonic Foraminifera *(U. Pflaumann)*

Saturday/Sunday, Sept. 19/20 : Sediment Waves and Sediment Drifts: Monitors of Global Change in Deep Water Circulation *(J. Mienert, W.-C. Dullo, R. Flood; D. Stow, L. Keigwin)*

Saturday/Sunday, Sept. 19/20 : Pelagic Biogeography *(D. Boltovskoy, A. Pierrot-Bults)*

Sunday, Sept. 20 : Stable Isotopes in Paleoceanography *(M. Fontugne, W. Showers)*

<table>
<tr><th></th><th></th><th>Morning Sessions</th><th>Afternoon Poster Sessions</th><th>Invited Lectures</th><th>Evening Events</th></tr>
<tr><td rowspan="5">CONFERENCE</td><td>MON</td><td><u>SYMPOSIUM I</u>
Sea Level and the Ice-Land-Ocean Connection</td><td rowspan="2">Sea Level
Ocean and Atmosphere Paleochemistry
Microfossil and Organic Chemical Tracers
Trace Elements
The Tropical Ocean
Pacific Ocean
Indian Ocean
Atlantic Ocean
Marginal Seas
Advances in Paleoceanographic Methodology
Pelagic Biogeography</td><td><u>M. Leinen:</u>
Land-Sea Connections</td><td>Business Meetings:
NAD
Global Change Coring
COMEMIR-PASROC</td></tr>
<tr><td>TUE</td><td><u>SYMPOSIUM II</u>
PALEOGEOSECS, Coastal and Open Oceans</td><td><u>J. Jouzel:</u>
The Ice Core Record of Global Change</td><td>Paleomusicology Concert</td></tr>
<tr><td>WEN</td><td><u>SYMPOSIUM III</u>
Deglaciations and 100-Year-Scale Events</td><td colspan="2">Sight Seeing Tours / Excursions</td><td>Conference Dinner</td></tr>
<tr><td>THU</td><td><u>SYMPOSIUM IV</u>
Tertiary Oceans and Climatic Evolution</td><td rowspan="2">Deglaciations and 100-Year Scale Events
Tertiary Oceans
Mesozoic and Ancient Oceans
The High-Latitude Ocean
Arctic Ocean
Norwegian-Greenland Seas
Northern North Atlantic
Southern Ocean
Ocean-Atmosphere Modelling
Paleoceanography of the Eastern Equatorial Pacific: the ODP Leg 138 Record</td><td><u>N. McCave:</u>
The Record of Bottom Current Speeds</td><td>Public Lecture (in German)</td></tr>
<tr><td>FRI</td><td><u>SYMPOSIUM V</u>
Mesozoic Oceans and Seas</td><td><u>J.-C. Duplessy:</u>
160,000 Year Deep Water History</td><td></td></tr>
</table>

BUSINESS / COMMITTEE MEETINGS

Monday, Sept. 21, 6:30-8:00 p.m.: Nansen Arctic Drilling (NAD) *(D. Fütterer, L. Johnson, J. Thiede)*

Monday, Sept. 21, 6:30-8:00 p.m.: Phosphatic and Authigenic Sediments - A Record of Ocean Change (COMEMIR - PASROC) *(F. Abrantes, M. Wiedicke)*

Monday, Sept. 21, 8:00-9:30 p.m.: Coring Needs for Global Change Research in the 1990s and Beyond *(B. ul Haq, N. Pisias)*

Tuesday, Sept. 22, 1:30 p.m.: Friends of Arctic '91 - Luncheon

Saturday/Sunday, Sept. 26/27: Leg 138 Post-Cruise Meeting *(L. Mayer, N. Pisias)*

Saturday, Sept. 26 - Monday, Sept. 28: ODP-SGPP Panel Meeting *(J. McKenzie)*

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The cover photographs represent the five symposia of ICP IV:

Symposium I: Sea Level and the Ice-Land-Ocean Connection

Stevns Klint, Denmark, with a modern coastal terrace and a rocky shore, which developed in response to the Holocene sea-level rise. The stratigraphic sequence exposed at the face of the cliff consists of Upper Cretaceous chalks and bryozoan limestones, with the Fish Clay layer documenting the K/T boundary event and lowermost Tertiary biogenic shelf carbonates on top. Courtesy of Jörn Thiede, Kiel.

Symposium II: PALEOGEOSECS, Coastal and Open Oceans

The manipulator of the submersible ALVIN has placed a benthic barrel sampler above an active vent for collecting seep gases like methane, carbon dioxide, hydrogen sulphide and helium (Cascadia subduction zone off Oregon, 675 m water depth). Courtesy of Peter Linke, Kiel.

Symposium III: Deglaciations and 100-Year-Scale Events

Sea ice in the Fram Strait at the entrance to the Arctic Ocean. The picture displays an environment typical for the boreal oceans during deglaciation. Courtesy of Jörn Thiede, Kiel.

Symposium IV: Tertiary Oceans and Climatic Evolution

Pictorial diagram of a convergent margin. The picture represents tectonic activity during the Tertiary: the subduction processes along the "Pacific ring of fire" resulting in the establishment of the middle American landbridge and plate collisions between the African and Eurasian continents closing the Tethyan Ocean. Both processes lead to a major re-organization of ocean surface and bottom circulation.

Symposium V: Mesozoic Oceans and Seas

Deep-water octocoral of the group *Antipatharia*, representing the "warm Mesozoic Ocean". Photographed from submersible JAGO in 200 m water depth, off Mayotte Island, Comores. Courtesy of Wolf-Christian Dullo, Kiel.

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MARLOG Marine Logistik GmbH, Kiel
ME Meerestechnik-Elektronik GmbH, Trappenkamp
Walter G. Mühlau Universitätsbuchhandlung und Verlag GmbH & Co., Kiel

Fourth International Conference on Paleoceanography

ICP IV

21-25 September 1992

Welcome to ICP IV, welcome to Kiel !

The International Conferences on Paleoceanography were established to serve the need for an enhanced exchange of ideas and information among the paleoceanographic community. Like the ICP Conferences in Zürich (1983), Woods Hole (1986) and Cambridge (1989), the *Fourth International Conference on Paleoceanography (ICP IV)* is organized to bring together colleagues from the various paleoceanographic subdisciplines in a stimulating and scientifically intriguing environment.

The program for ICP IV builds on the tradition established by the previous Paleoceanography Conferences: the days of the Conference are divided into symposia on specific topics with presentations by selected speakers and poster sessions addressing a variety of paleoceanographic topics: there are no overlapping sessions in order to not exhaust our energy too easily; key-note lectures are given in the late afternoons. In addition, there are some workshops beeing held before the Conference and a few business meetings during and after the Conference.

Organization of ICP IV was only possible with the support of numerous colleagues from the various marine geo-institutions in Kiel. In particular, we are grateful to H. Bäcker, K. Emeis, G. Haass, H. Heyn, C. Hoffmann, A. Keir, F. Kögler, H. Köhrer-Wagner, O. Runze, F. Sirocko, and F. Werner.

We are pleased that so many of you from all over the world have been able to come together in Kiel to exchange ideas and to test hypotheses. On behalf of the paleoceanographic community and the organizing committee we would like to welcome all of you here in Kiel.

The ICP IV Organizing Committee

Wolfgang Berger (Bremen and LaJolla, CA); Dieter Fütterer (Bremerhaven); Klaus Herterich (Bremen); Dieter Lange (Rostock-Warnemünde); Michael Sarnthein (Kiel); Erwin Suess (Kiel); Jörn Thiede (Kiel); Ulrich von Rad (Hannover); Rainer Zahn (Kiel)

GENERAL INFORMATION

Meeting Place / Lecture Hall / Conference Office

All conference events (lectures, poster sessions, workshops, exhibitions, etc.) will be held in the Auditorium Maximum (main lecture hall) of the Christian-Albrechts-University at the Christian-Albrechts-Platz (Westring at Olshausenstraße; see map for location).

The conference office will also be in the Auditorium Maximum (main lecture hall). Office hours are: Sunday, Sept. 20th, 6-9 p.m., Monday through Friday, 8 a.m.-6 p.m.

Office phone and fax numbers are (ph) +49-431-880-4036 or 4711, (fax) +49-431-880-1589.

Public Transportation

to **Auditorium Maximum** (main lecture hall): take busses number 2, 12,41; get off at bus stop "Universität"

to **Conference Dinner** at the "Drathenhof" (Wednesday evening): see information below

to **Hamburg Airport**: take airport shuttle "Kielius" from Kiel main station. Shuttle takes about 1 hour and 30 minutes to Hamburg airport: a.m. 3:30/4:30/7:00/9:00/ 11:00, p.m. 1:00/3:00/5:00. One-way fare is DM 17.50.

Telephone and Fax Services

Telephone services are available at the nearby post office. There is one telephone available at our registration desk. If you use this one we will charge you according to what is shown on the digital read-out. Please pay directly after you made your call (no calling cards, please), in return you will get a receipt.

Coffee Breaks, Lunch and Dinner

During coffee breaks and the afternoon poster sessions coffee/tea will be served free of charge. Soft drinks are available for a moderate price.

There are numerous restaurants in the vicinity of our meeting place where you can get lunch at affordable prices. See inside front cover for location map and list of restaurants.

The students´ restaurant directly aside the lecture hall offers lunch at a price of DM 7.50. Tickets are available at the registration desk.

Banking / Money Exchange

The *Kieler Volksbank* is making banking and money exchange services available in the main lobby of the conference center. All convertible currencies are accepted; no exchange fees for cash exchange, a modest fee will be charged for cashing-in traveller cheques.

The banking service is available **Sunday, Sept. 20, 6 p.m.-9 p.m.**, **Monday/Tuesday, Sept. 21/22, 1 p.m.-3 p.m.**, and **Wednesday, Sept. 23, 9:30 a.m.-11 a.m.**

The *Kieler Volksbank* has agreed to extend their service to Thursday or Friday, if demand exists.

Paleomusicology

The Paleomusicology Concert will be held on **Tuesday, Sept. 22, 8:30 p.m.**, in the Auditorium Maximum (main lecture hall). Paleoceanographers will give a concert of instrumental and vocal music for paleoceanographers.

All Conference participants, their friends and accompanying family members are invited.

Sight Seeing Tours

Sight seeing tours and field trips will take place **Wednesday afternoon**. For further information see bulletin board at the conference office.

Conference Dinner

The Conference Dinner will be held **Wednesday night, Sept. 23, 7:30 p.m.**, after the excursions/sight seeing tours at the "Drathenhof", a traditional Schleswig-Holsteinian restaurant in Molfsee right in front of the open-air museum.

All excursions/sight seeing tours will end at the Drathenhof. Before dinner - depending on the weather situation - we will have a guided tour through the open-air museum.

The dinner fee of DM 40.- will be collected at the registration desk and includes the full dinner plus bus transfer back into town after dinner.

Public Lecture

On **Thursday night, Sept. 24, 8:00 p.m.**, Prof. Hartmut Graßl will give an overview talk on "Globale Klimaänderungen: Agieren statt Reagieren" (in German).

The lecture will be introduced by Mrs. M. Tidick, S-H's Minister for Education, Science and Culture.

Morning Sessions

The lecture hall is equipped with a 35 mm slide and overhead projectors. Speakers should hand their slides to the projectionists in the lecture room 15 minutes before the sessions start. Make sure your slides have a clear mark in the upper righthand corner so that the projectionists can load the slide trays without much experimenting around.

Upon arrival please check your name off in the list at the bulletin board so that the session convenors know that you have arrived and will give your talk.

30 minutes are allocated for each talk and include time for discussion.

Poster Sessions

Poster sessions will be in the afternoons according to the schedule shown in the daily program further below. All posters will be up for two days (Mon/Tue and Thu/Fri). Posters scheduled for the Mon/Tue sessions should be put up Sunday evening and/or Monday during lunch break, and put down Tuesday evening; the Thur/Fri posters should be put up Wednesday afternoon and/or Thursday during lunch break, and put down Friday evening.

Positions of individual posters within each session will be coordinated by the session convenors.

Industrial Exhibitions

Companies present their products which are of relevance for marine geosciences and paleoceanographic research in the main lobby opposite to the lecture room.

BUSINESS/COMMITTEE MEETINGS

(For locations of the meetings see bulletin board)

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Convenors: D. Fütterer, L. Johnson, J. Thiede

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Convenors: F. Abrantes, M. Wiedicke

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Convenors: B. ul Haq, N. Pisias

Saturday/Sunday, Sept. 26/27: **Leg 138 Post-Cruise Meeting**
Convenors: L. Mayer, N. Pisias

Saturday, Sept. 26 - Monday, Sept. 28: **ODP-SGPP Panel Meeting**
Convenor: J. McKenzie

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Convenors: L. Mayer, N. Pisias

Saturday, Sept. 26 - Monday, Sept. 28: **ODP-SGPP Panel Meeting**
Convenor: J. McKenzie

8:30 **Opening of ICP IV**
Professor Karin Peschel, President of Christian-Albrechts-University Kiel: *Marine Science and Paleoceanography in Kiel*

Jörn Thiede, on behalf of the ICP IV organizing committee: *Welcome and Technical Remarks*

SYMPOSIUM I
"Sea Level and the Land-Ice-Ocean Connection"
Convenors: M. Leinen, U. von Rad

9:00 Timing, amplitude, and rate of sea level change: stratigraphic modelling and change: stratigraphic modelling and recent seismic data from the New Jersey Margin (Reynolds, D., M.S. Steckler, N. Christie-Blick, G.S.Mountain, K.G. Miller, and B.J. Coakley)

9:30 Icehouse sea-level changes, depositional sequences, and the New Jersey Margin (Miller, K., G.S. Mountain, N. Christie-Blick, J.D. Wright, L.C. Peterson, and P.K. Swart)

10:00 Unraveling the influence of paleoceanographic, sea level and tectonic controls on long-term carbonate platform evolution: results from ODP Leg 133 on NE Australian margin (McKenzie, J., A.Isern, H. Elderfield, P. Davies, A. Palmer-Julson, and ODP Leg 133 Shipboard Scientific Party)

10:30 Recent eustatic variations (Pirazolli, P.)

11:00 *Coffee Break*

11:30 Response of the Indian Ocean monsoon to oceanic, atmospheric and global ice-volume conditions over orbital and secular time scales (Clemens, S., and F. Sirocko)

12:00 Sequencing of events in the North Pacific with respect to continental dust availability (Hovan, S., D. Rea, and N. Pisias)

12:30 Continental loess deposits: a record of climatic variability during the Neogene (Kukla, G.)

13:00 What are Heinrich events trying to tell us? (Bond, G.and W.S. Broecker)

13:30 Biomarker perspective on oceanographic changes in the Northeast Pacific during the last glacial-interglacial transition (Prahl, F., M. Sparrow, and B. Eversmeyer)

14:00 *Lunch Break*

15:00 *POSTER SESSIONS*

17:00	Keynote Lecture:	M. Leinen, *The Land-Sea Connection* (Main Lecture Hall)
18:30	Business Meeting:	Nansen Arctic Drilling
18:30	Business Meeting:	COMEMIR-PASROC
20:00	Business Meeting:	Coring Needs for Global Change Research in the 1990s and Beyond.

SYMPOSIUM II
"PALEOGEOSECS: Coastal and Open Oceans"
Convenors: E. Boyle, M. Kastner, E. Suess

8:30	Comparison of Cd and $\delta^{13}C$ evidence for glacial/interglacial paleochemical distributions (Boyle, E.)
9:00	The stable isotope record of deep and intermediate water masses in the southern hemisphere: 0-30,000 years B.P. (Charles, C., J. Lynch-Stieglitz, and R.G. Fairbanks)
9:30	North Atlantic surface waters and the conveyor belt: variability during the past 30 ka (Labeyrie, L., J.C. Duplessy, M. Arnold, G. Duprat, G. Bond, and W. Broecker)
10:00	$\delta^{15}N$ constraints on the utilization of nutrients in the oceans: application for paleoceanographic problems (Altabet, M.A., R. François, and W.B. Curry)
10:30	*Coffee Break*
11:00	Trace metals incorporation in foraminiferal calcite as a function of water column chemistry: model results and examples from Sr/Ca and REE/Ca data (Elderfield, H., C.J. Bertram, and J. Erez)
11:30	Paleogeochemical records of Southern Ocean productivity, nutrients and sea ice: links to glacial-interglacial atmospheric CO_2 changes (Froelich, P., R. Mortlock, C. Charles, L. Burckle, J. Hays, G. Bareille, J. Pichon, M. Labracherie, L. Labeyrie)
12:00	Boron isotope paleoceanography (Spivack, A.)
12:30	A view from the bottom up: constraints on glacial deep water circulation and alkalinity from benthic foraminiferal barium (Lea, D.)
13:00	Mid-depth circulation of the subpolar North Atlantic during the LGM (Oppo, D., S. Lehman, L.D. Keigwin, and N. Weicker)
13:30	*Lunch Break*
13:30	Friends of Arctic '91 - Luncheon
15:00	*POSTER SESSIONS*
17:00	Keynote Lecture: J. Jouzel, *The Ice Core Record of Global Change* (Auditorium Maximum, Main Lecture Hall)
20:30	Paleomusicology Concert (Auditorium Maximum, Main Lecture Hall)

SYMPOSIUM III

"Deglaciations and 100-Year-Scale Events"

Convenors: E. Bard, M. Sarnthein, G. Wefer

8:30	Bermuda coral reef record of the last 1000 years (Pätzold, J., G. Wefer)
9:00	High-resolution $^{230}Th/^{234}U$-dated sea-level record from Barbados spanning the past 30,000 years (Fairbanks, R., J. Rubenstone, Y. Lao, T. Guilderson, and A. Zindler)
9:30	Modelling record of deglaciations (Herterich, K., and G. Lautenschlager)
10:00	Present status of the radiocarbon calibration for the Late Pleistocene (Bard, E., M. Arnold, and B. Hamelin)
10:30	*Coffee Break*
11:00	Santa Barbara Basin varve record of the last 500 years (Lange, C., A. Schimmelmann, and W. Berger)
11:30	U^{k}_{37} secular geochemical records of the last 400,000 years (Eglinton, G., M. Conte, M. Rosell, and M. Zhao)
12:00	The meltwater world (Sarnthein, M., M.S. Weinelt, H. Erlenkeuser, and E.Jansen)
12:30	Orca Basin: a hundred-year resolution record of Holocene paleoclimatic changes in the Golf of Mexico (Kennett, J.)
13:00	*Lunch Break*
14:00	Sight Seeing Tours / Excursions For departure times see bulletin board
19:30	Conference Dinner at the "Drathenhof" (Kiel-Molfsee, at the Open Air Museum)

SYMPOSIUM IV

"Tertiary Oceans and Climatic Evolution"

Convenors: W. Berger, D. Fütterer

8:30	Cenozoic climate and ocean modelling (Barron, E.)
9:00	Effect of Cenozoic gateway changes on the ocean circulation (Crowley, T., U. Mikolajewitz, and E. Maier-Reimer)
9:30	Cenozoic plateau uplift and paleoceanography (Ruddiman, W.)
10:00	Cenozoic chemical mass balances in the world ocean (Delaney, M.L.)
10:30	*Coffee Break*
11:00	Neogene deep-sea carbonate sedimentation: some basic questions (Berger, W.H.)
11:30	Onset of glaciation in the northern hemisphere: steps on a cooling trend (Jansen, E.)
12:00	Late Neogene climate change: a Southern Ocean perspective (Hodell, D.)
12:30	The terrestrial and marine record of Cenozoic glaciation in the southern hemisphere (Webb, P., and D. Harwood)
13:00	*Lunch Break*
15:00	*POSTER SESSIONS*

17:00	Keynote Lecture:	N. McCave, *The Record of Bottom Current Speeds in Deep Sea Sediments* (Auditorium Maximum, Main Lecture Hall)
20:00	Public Lecture	H. Graßl, *Globale Klimaänderung: Agieren statt reagieren.* (in German) with an introduction by Ms. M. Tidick, S-H´s Minister of Science, Education and Culture (Auditorium Maximum, Main Lecture Hall)

SYMPOSIUM V

"Mesozoic Oceans and Seas"

Convenors: E. Barron, M. Cita, F. Gradstein, W.W. Hay

8:30	Milankovitch in the greenhouse (Fischer, A.G., and D.J. Bottjer)
9:00	Orbital forcing of cyclicity in the Mesozoic (Huang, Z.)
9:30	Pangean climatology and oceanography (Hay, W.W.)
10:00	Atmospheric CO_2 and Mesozoic paleogeology (Kump, L.R.)
10:30	*Coffee Break*
11:00	The Cretaceous superplume episode (Larson, R.L.)
11:30	Kimmeridgian and black shale paleoceanography (Thurow, J.)
12:00	Drilling atolls and guyots (ODP Leg 144): preliminary results and oceanographic implications (Premoli-Silva, I., J.A. Haggerty, and Leg 144 scientific party)
12:30	Jurassic through Early Cretaceous sedimentation history of the tropical Pacific (Ogg, J.G.)
13:00	*Lunch Break*
15:00	*POSTER SESSIONS*
17:00	Keynote Lecture: J.-C. Duplessy, *160,000 Year Deep Water History* (Auditorium Maximum, Main Lecture Hall)
18:00	Closing Remarks and Farewell

POSTER SESSIONS OVERVIEW

1.1 SEA LEVEL
Convenors: A. Droxler (Houston), A. Mix (Corvallis)

OCEAN AND ATMOSPHERE PALEOCHEMISTRY

1.2 MICROFOSSIL AND ORGANIC CHEMICAL TRACERS
Convenors: J. Barnola (Saint-Martin-d'Herès), C. Sancetta (NSF, Washington)

1.3 TRACE ELEMENTS
Convenors: A. Mangini (Heidelberg), P. Müller (Bremen)

THE TROPICAL OCEAN

1.4 PACIFIC OCEAN
Convenors: R. Bonnefille (Marseille), C. Ravelo (Santa Cruz)

1.5 INDIAN OCEAN
Convenors: F. Sirocko (Kiel), E. Vincent (Marseille)

1.6 ATLANTIC OCEAN
Convenors: J. Pätzold (Bremen), R. Ross (Kiel)

1.7 MARGINAL SEAS
Convenors: K. Emeis (Kiel), C. Hemleben (Tübingen)

1.8 ADVANCES IN PALEOCEANOGRAPHIC METHODOLOGY
Convenors: T. Oba (Kanazawa), R. Stein (Bremerhaven)

1.9 PELAGIC BIOGEOGRAPHY (SCOR WG 93)
Convenors: D. Boltovskoy (Buenos Aires), A. Pierrot-Bults (Amsterdam)

2.1 DEGLACIATIONS AND 100-YEAR-SCALE EVENTS
Convenors: N. Karpuz (Bergen), P. Wang (Shanghai)

2.2 TERTIARY OCEANS
Convenors: H. Thierstein (Zürich), R. Thunell (South Carolina)

2.3 MESOZOIC AND ANCIENT OCEANS
Convenors: J.P. Kennett (Santa Barbara), K. Stattegger (Kiel)

THE HIGH-LATITUDE OCEAN

2.4 ARCTIC OCEAN
Convenors: J. Thiede (Kiel), T. Vorren (Tromsø)

2.5 NORWEGIAN-GREENLAND SEAS
Convenors: U. Bleil (Bremen), P. Schäfer (Kiel)

2.6 NORTHERN NORTH ATLANTIC
Convenors: E. Erba (Milano), H. Heinrich (Hamburg)

2.7 SOUTHERN OCEAN
Convenors: L. Labeyrie (Gif-sur-Yvette), G. Wefer (Bremen)

2.8 OCEAN-ATMOSPHERE MODELING
Convenor: K. Herterich (Bremen), D. Seidov (Moscow)

2.9 PALEOCEANOGRAPHY OF THE EASTERN EQUATORIAL PACIFIC: THE ODP LEG 138 RECORD
Convenors: J. Farrell (Providence, RI), N. Pisias (Corvallis)

POSTER SESSIONS

PROGRAM

1.1 SEA LEVEL

Convenors: A. Droxler (Houston), A. Mix (Corvallis)

(Monday/Tuesday)

Sea-level and climate control on the evolution of an isolated carbonate platform: the Queensland Plateau, NE Australia (ODP Leg 133) (Ch. Betzler and T. Brachert)

Late Holocene paleoenvironmental and sea-level reconstructions along the South Carolina coastline (E.S. Collins, D.B. Scott, and P.T. Gayes)

Morphology and sedimentary evolution of the deep fore-reef slopes of the Comoro Islands in comparison with the Red Sea and the Caribbean (W. Dullo and D. Blohmeier)

Calibrating ^{14}C-ages with ^{230}Th ages of corals from New Guinea and Vanuatu (R.L. Edwards, J.W. Beck, G.S. Burr, S.C. Gray, F.W. Taylor, D.J. Donahue, and R.M. Druffel)

Holocene sea level determination relative to the Australian Continent -U/Th (TIMS) and ^{14}C (AMS) dating of coral cores from the Abrolhos Islands (A. Eisenhauer, G.J. Wasserburg, J. Chen, G. Bonani, L. Collins, Z.R. Zhu and K.H. Wyrwoll)

The precise timing and amplitude of sea levels between 85 and 230 ka from ^{230}Th ages of fossil corals from Barbados, West Indies (C.D. Gallup, R.L. Edwards, and R. G. Johnson)

Eustasy, determined from sequence stratigraphy, linked to the plio-Pleistocene oxygen isotope record of global ice volume (G.A. Haddad)

Tertiary sea level changes on the Iceland-Faeroe Ridge (Ch. Krawczyk, A. Omlin, and F. Theilen)

Holocene sea-level rise, Bermuda (D. Meischner)

Shoreline oscillation study using satellite data of south-east coast of India (N. Radhakrishnan and R. Krishnamoorthy)

Late Pleistocene sea-level and climate change based on high-precision mass-spectrometric ^{230}Th ages of speleothems from the Bahamas (D. A. Richards, P.L. Smart, and R.L. Edwards)

Atoll Drilling in the Northwest Pacific: first results of ODP Leg 143 (U. Röhl and Leg 143 shipboard scientific party)

Sediment chemistry and benthic foraminifera in salt marsh sequences as an indicator of relative sea-level rise over the last 1,500 years (J.C. Varekamp and E. Thomas)

A high resolution sea level record for the late Neogene from Wanganui Basin, New Zealand (G.S. Wilson)

OCEAN AND ATMOSPHERE PALEOCHEMISTRY

1.2 MICROFOSSIL AND ORGANIC CHEMICAL TRACERS

Convenors: J. Barnola (Saint-Martin-d'Heres), C. Sancetta (NSF Washington)
(Monday/Tuesday)

Late Quaternary Paleoproductivity variations in the NE and Equatorial Atlantic: Diatom and C_{org} evidence (F. Abrantes, U. Pflauman, K. Winn, and M. Sarnthein) *NATO ARW abstract*

Biomarkers and carbon isotopes in organic carbon-rich sediments. Biologic response of a modern lake to environmental changes (D. Ariztegui, J.A. McKenzie, and P. Farrimond)

Phosphorites as upwelling product (G.N. Baturin)

Controls on the carbon isotope composition of sedimentary organic matter and carbon cycling in a permanently anoxic basin: an actualistic lacustrine model (S. Bernasconi, R. Peduzzi and J.A. McKenzie)

Carbon isotopes in planktonic foraminifera as a measure of paleoproductivity in the upwelling regions off Oman, NW- and SW-Africa (G. Ganssen, R. Schneider, and R. Zahn) *NATO ARW abstract*

Early Pleistocene glacial-intergalcial diatom and radiolarian assemblages from the Eastern Equatorial Pacific (K. Kennington)

Primary production: the diatom record in East Atlantic surface sediments (J.J. Knaack, M. Sarnthein, and U.Treppke)

Diagenesis of organic matter in siliceous sediments from the Japan Sea (E. Lichtfouse, C. von Ossietzky, and J. Rullkötter)

Detection of magnetic bacteria in deep-sea sediments - dependence on geochemical parameters (H. Petermann and U. Bleil)

Marine sedimentary organic $\delta^{13}C$ as a proxy for ocean/atmospere CO_2 concentrations: recent observations and models (G.H. Rau)

Palaeoceanographic implications of organic molecular stratigraphy data: a combined field/analytical assessment study (A. Rosell, J.F. Carter, G. Eglinton, A. Castellnou, and J. Grimalt)

The relation between dissolved cadmium and phosphate in modern seawater with implications for the use of cadmium as paleonutrient tracer (P.M. Saager, H. J.W de Baar, and R.N. Nolting) *NATO ARW abstract*

Diatoms in sediment traps from the Gulf of California (C. Sancetta, R. Thunell, L. Keigwin, and D. Murray)

Oxygen isotopes in biogenic silica: glacial - interglacial variations in temperature and seawater isotopic composition (A. Shemesh)

The enrichment of ^{13}C in marine kerogen during late Oligocene as the result of a coincidence of the drop in atmospheric CO_2 level and the enrichment of ^{13}C in dissolved oceanic carbon (I. Vető, E. Hertelendi, M. Hetényi, A. Nagymarosy, and A. Brukner-Wein)

Molecular indicators of palaeoproductivity: total pigment and alkenone-alkenoate abundances as primary biomass indicators compared to TOC and coccolith abundances (J. Villanueva, J. Grimalt, A. Rosell, and G. Eglinton, R. Hearn, R. Jordan, C. Summerhayes, and R. Kroon)

Pore water profiles, diagenesis and upwelling: an example from the benthic BOFS transect towards NW Africa (S.J. Wakefield)

Distribution of $\delta^{13}C_{\Sigma CO2}$ and trace metals in the ocean: implications for benthic $\delta^{13}C$ and Cd/Ca records as proxies for intermediate-depth nutrient cycling and the atmosphere's paleo-chemistry (R. Zahn and R. Keir) *NATO ARW abstract*

1.3 TRACE ELEMENTS

Convenors: A. Mangini (Heidelberg), P. Müller (Bremen)

(Monday/Tuesday)

Geochemical variations in Mn-crusts of different water depths during the last 300,000 years - implications to the water column? (N. Baur, K. Gögen, A. Mangini, A. Eisenhauer, and E. Pernicka)

Sea surface temperature from coral Sr/Ca ratios (J. W. Beck, R.L. Edwards, E. Ito, F.W. Taylor, J. Recy, F. Rougerie, P. Joannot, and C. Henin)

Cadmium/calcium and carbon isotope reconstructions of the glacial NE Atlantic water column (C. Bertram, N.J. Shackleton, J. MacDonald, and H. Elderfield)

Upwelling signals off North West Africa during the last 30ka (N.A.S. Beveridge and H. Elderfield)

The early diagenetic formation of "barite fronts" (H.-J. Brumsack)

A new palaeothermometer: the magnesium to calcium ratio in benthic ostracod valves (P. De Deckker, T. Corrège, J.M.G. Shelley and A.R. Chivas)

Great Barrier Reef coral and Halimeda cadmium-to-calcium ratios during the Holocene (M.L. Delaney, L.J. Linn, E.R.M. Druffel, S. Griffin, and P.J. Davies)

High resolution profiles of 10-beryllium, 230-thorium and 231-protactinium of two sediment cores from the Galapagos microplate, Eastern Equatorial Pacific: climatic and geochemical information (M. Frank, A. Eisenhauer, A. Mangini, D. Eckhardt, M. Suter, G. Bonani and W. Wölfli)

High resolution measurements of 231-protactinium in manganese-crusts (M. Frank, A. Eisenhauer, and A. Mangini)

Vanadium in planktonic foraminifera as a paleoceanographic tracer of bottom-water redox conditions (D. Hastings, S. Emerson, B. Nelson, J. Erez, and A. Mix)

Global ocean distribution of dissolved silicate in near-surface waters and its relationship to phosphate distribution (U.C. Herzfeld, J.L. Reid, and W. Berger)

Paleoproductivity of the Southern Ocean inferred from radionuclide tracers (N. Kumar, R. Gwiazda, R.F. Anderson, P.N. Froelich, B. Dittrich, P. Kubik, and M. Suter)

Chemistry of a recent (0-1700 yrs BP) Mn-Fe-coated pteropod pavement in the N.E. Atlantic Ocean: chemical signals for preservation vs. dissolution (M.J. Melkert)

Late Quaternary benthic foraminifera cadmium records: western equatorial Pacific and north-western Pacific (N. Ohkouchi, H. Kawahata, M. Okada, M. Murayama, and A. Taira)

Marine barite as a potential recorder of paleo-marine chemistry (A. Paytan, M. Kastner, E. Martin, and T. Herbert)

Uranium in foraminiferal calcite as a recorder of changes in sea-water Uranium concentration (A.D. Russell, S. Emerson, B. Nelson, J. Erez, and A. Mix)

Geochemistry of Silurian and Early Devonian black shales and cherts (Graptolitenschiefer) from Thuringia and Sardinia (B. Schnetger)

Barium palaeoproductivity records from mesotrophic ocean margin provinces recorded over the last 250,000 years (G.B. Shimmield, S. Derrick, D. Kroon, J. Lloyd, G. McNeill, A. Matthewson)

Evidence from Cd/Ca ratios in benthic and planktonic foraminifera for variations in upwelling intensity in the California Current (A. van Geen)

Reconstruction of glacial/Holocene changes in particle rain rate in the South Indian Ocean as recorded by ^{231}Pa, ^{230}Th and U in sediments (E.F. Yu, M.P. Bacon, and R. Francois)

THE TROPICAL OCEAN

1.4 PACIFIC OCEAN

Convenors: R. Bonnefille (Marseille), C. Ravelo (Santa Cruz)

(Monday/Tuesday)

Rapid growth of deep-sea benthic foraminifera from the San Pedro Basin, California borderland (B.H. Corliss and K. Silva)

Palaeotemperature reconstruction of the Western Coral Sea throughout the last 120.000 years using chemical analyses of benthic ostracod shells (T. Corrège)

A Little Ice Age coral record from the tropical South Pacific (T.J. Crowley , T.M. Quinn, and F. W. Taylor)

Quatenary carbonate preservation record at intermediate water depths: ODP Holes 817A and 818B, Townsville Trough, Northeast Australia (G.A. Haddad, A.W. Droxler, D. Kroon, and D. Muller)

Glacial to post-glacial changes in the tropical planktonic foraminiferal $\delta^{13}C$ record: a paleoproductivity reconstruction (J.C. Herguera and W.H. Berger)

Direct correlation of southern hemisphere terrestrial and marine paleoclimatic records from the last three glacial cycles: evidence from Site 594 (45°31'S, 174°57'E) (L.E. Heusser and G. van de Geer)

Paleoceanography of the Northeast Australian Margin: the effects of changing climatic and oceanographic conditions on carbonate sedimentation (A.R. Isern, J.A. McKenzie, and T. Fichefet)

A detailed investigation of the benthic regime in the Clarion-Clipperton geological province of the Pacific (E.A. Kontar)

Regional versus oceanwide transfer functions: palaeo-temperature estimation in the western Pacific in the Late Quaternary (J. Le and N. J. Shackleton)

Late Pleistocene dissolution patterns in the southwest Pacific (J.I. Martínez)

LGM and Holocene $\delta^{13}C$ profiles from the Indian Ocean off Western Australia (D.C. McCorkle, H.H. Veeh, and D.T. Heggie)

Seismic stratigraphy of the Ontong Java Plateau: paleoceanographic significance (D.C. Mosher and L.A. Mayer)

Late Pleistocene $\delta^{13}C$ variability in the western equatorial Pacific (M. Okada, N. Ohkouchi, A. Taira)

Living (stained) benthic foraminifera from the low-oxygen environments of the Sulu Sea (Philippines) (A.E. Rathburn and B.H. Corliss)

Sporen and pollen composition of eolian suspension over the ocean as an indicator of climatic zonality (S. Safarova)

High resolution analysis of the carbonate-rich sediment core 74P from the Ontong-Java Plateau (Western Equatorial Pacific) (B. Schwarz, M. Segl, A. Mangini, M. Suter, G. Bonani, and W. Wölfli)

The modern atmospheric and oceanic surface circulation and its record in sediments of the southwest Pacific Ocean (J. Thiede, S. Nees, and H. Schulz)

Neogene-Quaternary climatic changes in the east-tropical Pacific (M. Ushakova and N. Blyum)

Plio- and Pleistocene sea-surface temperature history of the western Pacific (L. Wang)

1.5 INDIAN OCEAN

Convenors: F. Sirocko (Kiel), E. Vincent (Marseille)

(Monday/Tuesday)

Influence of monsoon on pelagic carbonate sedimentation in the equatorial Indian Ocean; high-resolution record from a 54 m piston core (F. C. Bassinot, L. Labeyrie, E. Vincent, L. Beaufort, Y. Lancelot, L. Meynadier, and J.P. Valet)

Sonostratigraphy of equatorial Indian Ocean piston cores: toward a rapid and high-resolution tool for tracking dissolution cycles in Pleistocene carbonate sediments (F. C. Bassinot, L. Beaufort, Y. Lancelot, and E. Vincent)

Late Quaternary faunal record of sea-surface condition in the eastern tropical Indian Ocean; implication for atmosphere-ocean circulation changes (M.-T. Chen, J.-J. Chen, and W.L. Prell)

The 0 to 3.5 ma benthic oxygen isotope stratigraphy at ODP Site 758, Bay of Bengal (J.-J. Chen, J.W. Farrell, D.W. Murray, and W.L. Prell)

Palaeoenvironments above the Exmouth Plateau, Western Australia, for the Brunhes Chron (P. De Deckker, P. Wells, A.R. Chivas, J. Cali, T. Corrège, D. D'Costa, J.M. Shelley, J.M.G. Shelley and W.S. Wickremeratne)

Southward expandings of the Somalian upwelling during the Late Quaternary (C.Vergnaud Grazzini, M-T. Vénec Peyré, J.P. Caulet, and H. El Foukali)

Interannual variability of particulate fluxes to the deep Arabian Sea (B. Haake, V. Ittekkot, T. RixenV. Ramaswamy, and R.R. Nair)

Foraminiferal and isotopic evidence for anomalous variation in monsoonal intensity and productivity in the Arabian Sea between 35-50 kyr (J.O.R. Hermelin and G.B. Shimmield)

50-meter piston cores taken in the tropical Indian Ocean (SEYMAMA/ SHIVA Expedition) (Y. Lancelot, Y. Balut, and the shipboard scientific party)

Rock magnetic properties as records of paleoclimate in oceanic cores of the western equatorial Indian Ocean (L. Meynadier, J.-P. Valet, N. Shackleton, R. Weeks, and F. Bassinot)

High resolution record of changes in monsoonal pattern over India over the last 4,500 years: foraminiferal evidences (R. Nigam and N. Khare)

A 170,000 year sea-surface temperature (SST) and organic carbon record from the Northern Indian Ocean (F. Rostek, G. Ruhland, F.C. Bassinot, P.J. Müller, E. Bard, L. Labeyrie, and Y. Lancelot)

Plio-Pleistocene palaeoceanography and productivity fluctuations of the western equatorial Indian Ocean (J.E. Swallow, B.M. Funnell, and T.D. Jickells)

Submarine morphology of the upper Indus Fan: an appraisal (M. Veerayya and S.M. Karisiddaiah)

1.6 ATLANTIC OCEAN

Convenors: J. Pätzold (Bremen), R. Ross (Kiel)

(Monday/Tuesday)

Absolute seasonal paleotemperatures in the eastern and western equatorial Atlantic: oxygen isotope results (K. Billups and H.J. Spero)

Radiolarian sedimentary imprint in Atlantic equatorial sediments: comparison with the yearly flux at 853 m (D. Boltovskoy, V.A. Alder, and A. Abelmann)

Reconstruction of vegetation zones in NW Africa from marine palynological data: consequences for the CO_2 atmospheric balance (L.M. Dupont)

Seasonal particle flux in some high production areas of the Eastern Atlantic (G. Fischer and G. Wefer)

Freshwater diatoms and phytoliths as signals of continental aridity (J.H.F. Jansen, E.M.Pokras, L.H.Burckle, and B.Stabell)

Observations on calcareous dinoflagellates in the phytoplankton and sediments off Cape Blanc (East Atlantic Ocean) (B. Kerntopf and H. Willems)

Palynomorph records of the last glacial-interglacial cycle in the Eastern Equatorial Atlantic (F. Marret)

Wind-controlled spatial and temporal thermocline/nutricline/productivity variation in the Equatorial Atlantic: 0-200ka (A. McIntyre, B. Molfino, M. Yarusinsky, and D. Verardo)

Tracing the Late Quaternary interbasin exchange in the Benguela Current System (H. Schmidt and G. Wefer)

Precessional forcing of paleoproductivity in the Eastern Angola Basin (R. Schneider, P.J. Müller, and G. Wefer)

Sea-surface temperatures in the North Atlantic during the early Holocene summer insolation maximum, 9000 years B.P. (H. Schulz and U. Pflaumann)

Astronomic tuning of high-resolution benthic $\delta^{18}O$ records from ODP-sites 658 and 659 for the last 5 million years vs. non-linear climatic dynamics (R. Tiedemann, M. Mudelsee, M. Sarnthein, and K. Stattegger)

Seasonal flux patterns of planktonic diatoms and silicoflagellates in the Guinea Basin (U.F. Treppke and C.B. Lange)

Recent surface water planktonic foraminifera off SW Africa, Angola Basin (E. Ufkes)

1.7 MARGINAL SEAS

Convenors: K. Emeis (Kiel), C. Hemleben (Tübingen)

(Monday/Tuesday)

Late Quaternary paleoceanography of the Banda Sea (S.M. Ahmad, L.D. Labeyrie, and F. Guichard)

Isotope stage two - the most extreme glacial time within the last 370,000 years and the following "deglaciation" - a record from the Central Red Sea (A. Almogi-Labin, C. Hemleben, H. Erlenkeuser, D. Meischner, and G. Bonani) *NATO ARW abstract*

Hydrocarbon gas plumes at the bottom of the Okhotsk and Japan Seas (V. Anikiev and A. Obshirov)

Micropaleontology of hydrothermal vents in the Guaymas Basin, Gulf of California, Mexico (A. Ayala-Lopéz)

Hydrographic changes between the Eastern and Western Mediterranean basin during the last deglaciation (C.J. Beets, G. Ganssen, S. Troelstra, K. van der Borg, and A.F.M. De Jong)

Distribution of Po-210 in the North Sea (J.P. Beks)

Quantitative reconstruction of Pliocene and Quaternary oceanography, Sea of Japan, based on marine ostracoda (T.M. Cronin, N. Ikeya, A. Kitamura, and T. Kamiya)

Sedimentary cycles in the Japan Sea (ODP-Leg 128): implications for changes in paleoclimate and paleoceanic circulation through Late Cenozoic times (M. Dersch-Hansmann, R. Stax, and R. Stein)

Unconsolidated bottom sediments of the Mediterranean Sea and paleoceanography (E.M. Emelyanov and K.M. Shimkus)

Hydrology of the Eastern Mediterranean during sapropel formation (M. Fontugne, M. Arnold, L. Labeyrie, S.E. Calvert, M. Paterne, and J.-C. Duplessy)

Regional and temporal changes in hydrothermal sedimentation in the Lau backarc basin, SW-Pacific (B. Gehrke)

Aeloian deposition of coarse-grained sediment into marginal seas: the view from Sylt (P. Goldschmidt, K. Bayerl, I. Austen, and R. Köster)

Paleoceanography of the Japan and Okhotsk Seas during the last glaciation and the Holocene (S.A. Gorbarenko)

Coral growth in recent reefs of the Red Sea (G. Heiss and W.-Chr. Dullo)

Paleoenvironment of the central Red Sea during the last 370,000 years (C. Hemleben, A. Almogi-Labin, H. Erlenkeuser, D. Meischner and R. Zahn)

Pleistocene chronology and paleoceanography of the Plio/Pleistocene boundary stratotype at Vrica (F.J. Hilgen and L.J. Lourens)

Pliocene to Early Pleistocene astronomically forced sea surface productivity and temperature variations in the Mediterranean (L.J. Lourens, A. Antonarakou, F.J. Hilgen, C. Vergnaud-Grazzini and W.J. Zachariasse)

The East Greenland Continentla Margin (65°N): ice sheet decay and sediment fluxes since the last deglaciation (J. Mienert and A. Wittmaack)

The Persian Gulf: giant sediment waves as indicators of long-term current activity? (J. Mienert, J. Thiede, and K. Maraschi)

Power spectrum analyses of storm layers in Holocene sediments of Kiel Bay: a tool for palaeoclimatic reconstruction? (D. Milkert and U. Hentschke)

Oceanography of the Gulf of Tehuantepec, Mexico, indicated by radiolaria remains (A. Molina-Cruz and M. Martinez-Lopez)

Quaternary calcareous nannofossils from the northern South China Sea and their stable isotope record (X. Su and W.-Z. Lü)

Climatic and paleoceanographic changes during the Late Quaternary in the western Gulf of Lions (Northwestern Mediterranean); the palynological record (J. Targarona, M. Canals, A. Calafat, K. Zonneveld, and G. Versteegh)

Seasonal sediment fluxes and varve formation in the Gulf of California (R. Thunell, C. Pride, E. Tappa, F. Muller-Karger, C. Sancetta, and D. Murray)

Quaternary paleoceanography of an active back-arc basin, Okinawa Trough amd its environs (H. Ujiie)

Pliocene saproel formation in the eastern Mediterranean: productivity, dissolution, and dilution (B. van Os)

Recognition of cyclic and non-cyclic environmental changes in the Mediterranean Pliocene: a palynological approach (G.J.M. Versteegh)

A stable isotopic record from the Caribbean: little ice age to 1991 (A. Winter, H.Erlenkeuser, R. Zahn, and C. Goenaga)

Pliocene paleotemperature reconstruction for the southern North Sea based on ostracoda (A.M. Wood, R.C. Whatley, and T.I. Cronin)

Pleistocene and Holocene sea level changes in the Black Sea and the Caspian Sea (V. Yanko)

Environmental and climatic interpretation of pollen, spores and dinoflagellate-cysts associations during the past 15,000 years in the Eastern Mediterranean (C.A.F. Zonnefeld)

1.8 ADVANCES IN PALEOCEANOGRAPHIC METHODOLOGY

Convenors: T. Oba (Kanazawa), R. Stein (Bremerhaven)

(Monday/Tuesday)

Reconstructing past ocean temperature using foraminifer fossil plankton: advantages of response surface methodology (D.M. Anderson, R. C. Thunell, M. Qingmin, and K. H. Anderson)

Test size variations of planktic foraminifers as response to climatic changes (H.A. Bauch)

A new interpretation of foraminiferal and oxygen isotope data (N. Blyum, S. Kolokolov, and N. Oskina)

The oxygen-18 content of recent biogenic silica (natural diatom associations and cultures) and possible implications on diatom isotope stratigraphy (R. Botz, U. Jakobi, and P. Stoffers)

Imaging the physical properties of deep sea sediments by full waveform transmission seismogramms across gravity cores (M. Breitzke and V. Spieß)

Improved biostratigraphic dating using progressive graphic age-depth correlations of DSDP/ODP Sites in the Atlantic Ocean (W. Brenner and T.C.W. Wolf)

Detection of fine-grained overspill turbidites using ostracods - some important implications for core interpretation (V. Drapala)

A multidisciplinary approach for the use of phytoplankton as indicators of paleoproductivity: example from Upper Cretaceous organic-rich carbonates in Israel (Y. Eshet, A. Almogi-Labin, and A. Bein)

Cortex, an XRF-scanner for chemical analyses of sediment cores (J.H.F. Jansen, S.J. van der Gaast, B. Koster, and A. Vaars)

The paleoecology and paleoceanography of *Florisphera profunda* in Late Quaternary sediments (R.W. Jordan, P.P.E. Weaver, and N.J. Shackleton)

Correlation between laboratory and *in situ* physical properties (D.C. Kim, K. Dadey, and R.H. Wilkens)

Glacial-interglacial changes in the upper ocean recorded by deep-living planktonic foraminifera (G.P. Lohmann)

Statistics define ecologic controls of fossil planktonic forams (B. Molfino)

Technique and calibration bias in paleoestimation (B. Molfino)

Laboratory experiments on the infaunal activity in benthic foraminifers (L. Moodley)

Magneto and oxygen isotope stratigraphy of Late Quaternary sediments from the Ceara Rise: Evidence for polarity events within the Brunhes epoch (N.R. Nowaczyk, W. Thießen, and S. Mulitza)

Oxygen and carbon isotopes of individual foraminiferal specimens collected from sediment traps in the Japan Trench (T. Oba, K. Uomoto, and S. Honjo)

SIMMAX, a transfer technique to deduce Atlantic sea surface temperatures from planktonic foraminifera - the EPOCH approach (U. Pflaumann, C. Pujol, M. Duprat, and L. Labeyrie)

Correlation of high-resolution echosounding and sediment physical property measurements on the Ceara Rise (M. Richter and M. Breitzke)

The **B**enthonic **F**oraminifera **T**emperature **E**xperiment (BFTREX): an *in situ* approach for detecting global warming impact (C.T. Schafer, F.E. Cole, and M A. Buzas)

Fractal analyses of sedimentary deep-sea record show evidence for non-linear behavior of the Earth's climate system (Leg 104 Site 643, Norwegian Sea) (M. Schulz, T.C.W. Wolf, and J. Thiede)

A stratigraphy for Core 658C, ODP Leg 108, using grey scale and magnetic susceptibility data (M.B. Smith, M. Zhao, and G. Eglinton)

Intraspecific stable isotope variability in the planktonic foraminifera *Globigerinoides sacculifer* (H.J. Spero and D.W. Lea)

Comparisons between the oxygen isotopic composition of pore water and *Globigerinoides ruber* in sediments from Hole 817c, Leg 133 (P.K. Swart)

Dimorphism in *C. wuellerstorfi*: significance for the carbon and oxygen isotope record (K. Winn and H. Erlenkeuser)

Low-magnesium calcitic tests of benthic foraminifera chemically mirror morphological deformations (V. Yanko and J. Kronfeld)

1.9 PELAGIC BIOGEOGRAPHY

Convenors: D. Boltovskoy (Buenos Aires), A. Pierrot-Bults (Amsterdam)

(Monday/Tuesday)

Diatom species distribution patterns in surface sediments of the SW-Pacific (J. Fenner)

Late Aptian-Maastrichian planktonic foraminferida water-depth stratification: evidence from the Sergipe Basin strata, NE Brazil (E.A.M. Koutsoukos)

Planktonic foraminifera dissolution in the tropical Atlantic (N.P. Lukashina)

Planktic foraminifers in mocness tows from the California Current during September, 1990 (J.D. Ortiz, A.C. Mix and R. Collier)

Temporal variations of meteorological features in a tropical coastal region - southeast coast of India (P. Perumal)

Radiolarian assemblages as indicators of transgressive and regressive paleobasin phases (on the basis of results in the sakhalin area) (I.M. Popova)

Abundance of Tithonian - Berriasian tintinnids in Western Carpathians and limits of their distribution (D. Reháková and J. Michalík)

Late Quaternary paleobiogeography of the Benguela Current, Walvis Ridge, SE Atlantic (H. Schmidt and G. Wefer)

Recent North Atlantic marine planktonic diatom seabed distribution: paleoceanographic significance (H. Schrader and L.H. Burckle)

Processes responsible for export productions of diatioms, silicoflagellates and radiolarians in the pelagic realms (K. Takahashi)

Planktic foraminiferal assemblage distribution of the tropical Pacific as basis for paleotemperature reconstruction: an evaluation using pattern recognition technique (K.-Y. Wei)

Seasonal trends and preservational biases of polycystine radiolaria in the northern California Current system (L.A. Welling and N.G. Pisias)

2.1 DEGLACIATIONS AND 100-YEAR-SCALE EVENTS

Convenors: N. Karpuz (Bergen), P. Wang (Shanghai)

(Thursday/Friday)

Grain-size variation in Northeast Atlantic sediments: response to deep circulation (B. Afergan and I.N. McCave)

Late-glacial shelf biostratigraphy. Potentials and problems (W.E.N. Austin)

Circulation changes on century and millennial time scales in the northern Atlantic (G.C. Bond, W.S. Broecker, J. McManus, and R. Lotti)

Drastic changes in NE-Atlantic deep-sea sediments and faunas - evidence of recurrent Late Quaternary ice surges (part 1) (S. Clasen, S. Huon, R. Jantschik, and D. Meischner)

Deglaciation of the Baltic Sea: new paleoceanographic maps and paleoceanography (E.M. Emelyanov)

Imprints of late Holocene NW European environmental changes on the radionuclide and stable isotope record of the Skagerrak sediments (H. Erlenkeuser)

Upper Holocene marine Skagerrak (NE - North Sea) deposits: sedimentologic investigations regarding the paleoclimate of the past 1,000 years (H.C. Hass)

Laminated glacial sediment horizons in the North Atlantic (Maury Channel, 3300 m water depth) (S.J.A. Jung, H. Erlenkeuser, A. Rosell, and M. Sarnthein)

The last glacial-interglacial transition in the South China Sea recorded by stable isotopes of benthic and planktonic foraminifera (H.R. Kudrass, J. Schönfeld, H. Erlenkeuser, K. Winn, and R. von Grafenstein)

Paleohydrography of the Baltic since the last deglaciation: the Darss Sill Gateway (W. Lemke, A. Kuijpers, G. Hoffmann, F. Tauber, D. Milkert, and R. Atzler)

High-resolution records of Late Quaternary paleoenvironmental change from the anoxic Cariacobasin (Venezuela) (H.-L. Lin, L.C. Peterson, J.T. Overpeck, D.W. Murray, S.E. Trumbore, and C. Schubert)

Paleoceanography of the Spitsbergen Margin and deglaciation history of its ice cap (J. Lloyd, D. Kroon, and G. Boulton)

The benthic foraminiferal response to glacial/interglacial transitions in a high-resolution core seen as a possible change in palaeoproductivity (S. Nees)

How did the recently presented drainage of the Baltic Ice Lake, from 12,700 bp, affect the climatic development in the circum-Atlantic region? (K. Nordberg and H. Bergsten)

Glacial to interglacial variations in East Atlantic deep-water circulation (M. Sarnthein, K. Winn, J.-C. Duplessy , L. Labeyrie, and H. Erlenkeuser)

Paleodischarge events on the Amazon Fan (W.J. Showers, B. Genna, and J. Karr)

Drastic changes in the NE-Atlantic deep-sea sediments and faunas - preservation patterns of calcium carbonate during the last 150,000 years (part 2) (C. Simet, M. Maslin, and C. Hemleben)

The last deglaciation in the South China Sea (P. Wang, I. Wang, and Y. Bian)

Meltwater episodes in the Norwegian-Greenland Sea during the last 60,000 years (M.S. Weinelt, M. Sarnthein, M. Arnold, H. Erlenkeuser, and E. Jansen)

The $\delta^{18}O$ signature of the North Atlantic deep water during the last glacial maximum, the Younger Dryas, and the Holocene in the northern East Atlantic (K. Winn, H. Erlenkeuser, L. Labeyrie, and M. Sarnthein)

2.2 TERTIARY OCEANS

Convenors: H. Thierstein (Zürich), B. Thunell (South Carolina)

(Thursday/Friday)

Cenozoic paleoceanography based on micropaleontological data: methods and results (M.S. Barash)

Reactions to solar pumping in the Rifian Corridor leading to the Messinian Salinity Crisis (R.H. Benson. D.A. Hodell, K. Rakic-El Bied, D.V. Kent, and L.-A.C. Hayek)

The trophic resource continuum model and Paleogene planktonic foraminifera (A. Boersma, I. Premoli-Silva, and P. Hallok)

Late Neogene benthic foraminifer morphotypes as indicators of the closure of the Isthmus of Panama (L. Bornmalm and B.A. Malmgren)

Variation in sediment composition of Leg 104 (Sites 642B and 643A) as an indicator of paleoenvironmental changes during discontinuities in the Late Miocene fossil record (P. Bruns, W.-Chr. Dullo, W. Hay, C. Wold, and T. Wolf)

Upper Pliocene climatic cycles: high-resolution marine pollen record from central Mediterranean (N. Combourieu-Nebout)

Nannoplankton paleogeography of Cenozoic Atlantic and Indian Oceans (O.B. Dimitrenko)

Pliocene carbonate system on the Queensland Plateau: evidence for carbonate lowstand shedding (A.W. Droxler, G.A. Haddad, D. Kroon, S. Gartner, W. Wei, and D. McNeill)

The Eocene/Oligocene in the Southern Ocean (W.U. Ehrmann and A. Mackensen)

High-resolution stable isotopic stratigraphy and paleoceanography in the middle Miocene, southwest Pacific (B.P. Flower and J.P. Kennett)

Palaeoceanographic interpretation of the North Atlantic based on benthic foraminifera (DSDP, leg 94) (G. Francés, F.J. Sierro and J. Civis)

Diachroneity of Neogene planktic foraminifera in the Atlantic Ocean (H. Hilbrecht)

Quantitative faunal evidence of Pliocene high-resolution, deep circulation fluctuations in the North Atlantic (S.E. Ishman and T.M. Cronin)

Neogene-Quaternary climatic zonation of the world ocean (E.V. Ivanova, N.S. Oskina, and N.S. Blyum)

Evolution of climate in the Indian Ocean during the Neogene (E.V. Ivanova)

A data base for global syntheses of Neogene DSDP and ODP microfossil data (D. B. Lazarus, J.-P. Beckmann, M. Biolzi, H. Hilbrecht, K. von Salis Perch-Nielsen, C. Spencer-Cervato, and H. R. Thierstein)

Upper Pliocene climate in NW Africa from marine palynology of ODP Site 658 (S. Leroy and L. Dupont)

Neogene carbonate accumulation and compensation depth changes in the Indian Ocean (L.C. Peterson and D.W. Murray)

Do paleo-climatic records exhibit the Hurst Phenomenon? (G. Poveda)

Carbon-13 depleted water mass in the northern North Atlantic in the earliest Eocene (B. Schmitz)

Marine Palynology in the Neogene North-Atlantic; A comparative study on the western and eastern basin (K.U. Schmidt)

Sandy contourites of the recent and Late Miocene Atlantic-Mediterranean gateways. What do they mean? (F.J. Sierro and J.A. Flores)

Benthic foraminiferal response to environmental changes following the K/T-boundary (R.P. Speijer)

Study of diachroneity of Neogene plankton and revised biostratigraphy (C. Spencer-Cervato, J.-P. Beckmann, M. Biolzi, M. Casey, H. Hilbrecht, D. B. Lazarus, K. von Salis Perch-Nielsen, and H. R. Thierstein)

Paleoclimatic instability across the Oligocene/Miocene boundary: Evidence based on planktonic foraminifera from the "oceanic record" (S. Spezzaferri)

Slow motion of oceanization in the Northern Ethiopian Rift System (A. Tessema)

The Paleocene benthic foraminiferal extinction (E. Thomas and N.J. Shackleton)

Cenozoic paleoenvironment changes according to calcareous nannoplankton (M. Ushakova)

Antarctic versus Arctic earth cooling events: Neogene coarse terrigenous particle sedimentation (ODP Legs 104, 105, and 114) (T.C.W. Wolf and J. Thiede)

High-resolution isotopic records from across the Eocene/Oligocene boundary: the search for Milankovitch periodicity (J.C. Zachos, T.M. Quinn, and K.C. Lohmann)

Northeastern Atlantic bottom waters during the Late Miocene and Early Pliocene (J. Zhang and D.B. Scott)

2.3 MESOZOIC AND ANCIENT OCEANS

Convenors: J.P. Kennett (Santa Barbara), K. Stattegger (Kiel)

(Thursday/Friday)

Productivity and planktic foraminiferal changes across the Cretaceous - Tertiary boundary in high latitudes (E. Barrera and G. Keller)

On benthic foraminiferal paleoenvironments across the K/T boundary, Negev, Israel (Ch. Benjamini, G. Keller, and L. Perelis-Grossovicz)

Cretaceous stratigraphy of the Exmouth Plateau, NE Indian Ocean (R. Boyd and Z. Huang)

"Oxygen minimum zone intensity" - a new methodology for semi-quantification based on ostracodes (Upper Cretaceous-South Tethys Margin) (E. Braccini and J.P. Peypouquet)

Micropalaeontology of boreal lower Cretaceous cycles (Aptian/Albian) in Northern Germany (P. Cepek, J. Fenner, A. Thies, and W. Weiß)

The paleoequatorial upwelling belt in the Mesozoic Pacific Ocean: results of ODP Leg 129 (E. Erba, Y. Lancelot, R.L. Larson, and M.Steiner)

Sensitivity of modeled Cretaceous coastal upwelling to Milankovitch scale insolation variation (A.T.J. Glancy, Jr and B.M.A. Arthur)

A model of the evolution of atmospheric CO_2 during Mesozoic and Cenozoic time (Y. Goddéris and L.M. François)

Features and origin of Jurassic to Tertiary radiolarian cherts associated with ophiolites in southern Central America (H.-J. Gursky)

Lower Carboniferous cherts in Germany and the paleoceanography of the Upper Paleozoic paleo-Tethys (H.-J. Gursky)

Flow of currents in the Cretaceous Tethys (W.W. Hay, W.-Chr. Dullo, C.N. Wold, K.-A. Tröger, S. Voigt, R. Höfling, and G. Frank)

Late Cretaceous calcareous nannofossil biochronology from the Atlantic Ocean (A. Henriksson)

Hydrodynamic controls of anoxia in continental interior seaways (P.W. Jewell)

Changing paleoceanographic conditions, the trophic resource continuum, and the response of the foraminiferal communities: a case study from the Cretaceous of the Sergipe Basin, Brazil (E.A.M. Koutsoukos)

Reconstruction of depositional environments for carbonate buildups of Dalmiapuram Formation (Early Cretaceous) in Tiruchirapalli District, Tamil Nadu, India (R. Krishnamoorthy)

An Early Campanian paleoceanographic event in the North Atlantic and Western Tethys? (W. Kuhnt)

Productivity as a major control of short-term organic cyclicity in the Kimmeridge rocks of Yorkshire (U.K.) (E. Lallier-Vergés, P. Bertrand, M. Boussafir, and N. Tribovillard)

Cretaceous-Neogene terrigenous fluxes in the Indian Ocean and the North Atlantic: a comparison (M.A. Levitan)

The Valanginian carbon isotope event: a first episode of greenhouse climate conditions during the Cretaceous (A. Lini, H. Weissert, and E. Erba)

Cyclic carbonate fluctuations in the early Cretaceous Tethys - paleoceanographic considerations (H. Mayer)

Palaeogene Tethyan seaways in the Indian subcontinent: a synthesis (M. Mohanti)

Cretaceous marine scenario in the Indian subcontinent: a synthesis (M. Mohanti)

Cretaceous ferromanganese and phosphatic hardgrounds on the western Pacific guyots (I.O. Murdmaa)

Variation of late Maastrichtian planktic foraminiferal faunas with 20 ka precession cycles (A.J. Nederbragt, G.M. Ganssen, and J. Smit)

Large-scale changes in the calcareous nannophytoplankton which built pure Mesozoic limestones (D. Noël and G. Busson)

Magmatic evolution of the Ural paleoocean (I. Seravkin)

Radiolarian mass abundance/high diversity, stable isotope variations, black shale sedimentation, and sea level changes in the mid-Cretaceous - an integrated approach (J. Thurow, J. Erbacher, and H. Strauss)

Triassic rifting and Tethyan paleoenvironment of a NE-Gondwanan passive margin (Nepal) (U. von Rad, S.B. Dürr, J.G. Ogg, and J. Wiedmann)

Some geological consequences of the Late Devonian - Early Carboniferous mantle super-plume of the Sudetes Mountains, SW Poland (B. Wajsprych)

The Late Devonian - Early Carboniferous mantle superplume concept: its lithotectonic and tectono-stratigraphic evidence in the Sudetes Mountains (B. Wajsprych)

Repeated extrinsic perturbations of the Cretaceous biosphere - a document from northern Tethyan sediments (H. Weissert, K.B. Föllmi and A. Lini)

Benthic foraminiferal morphotypes and primary production during the terminal Cretaceous (J.G.W. Widmark)

THE HIGH-LATITUDE OCEAN

2.4 ARCTIC OCEAN

Convenors: J. Thiede (Kiel), T. Vorren (Tromsø)

(Thursday/Friday)

Diatom assemblages in Arctic sea ice - Indicator for ice drift pathways (A. Abelmann)

Evaluation of porosity and wet bulk density of Arctic sediments by high-resolution measurements of electrical resistivity (U. Bergmann and H. Kassens)

Modern benthic foraminifera in surface sediments of the Central Arctic Ocean (H. Bergsten)

Late Quaternary Arctic sediments as indicators for different ice coverage (H. Bohrmann, R. Botz, P. Stoffers, and J. Thiede)

Distribution of recent ostracoda from the Arctic Ocean; application to late Neogene oceanography (T.M. Cronin, R.C. Whatley, T.R. Holtz, Jr and A.V. Shuckstes)

Anthropo-chemical pollutants: tracers for Arctic sea ice dynamics? (D. Dethleff, J. Hansen, H. Kassens, S. Melnikov, D. Nürnberg, G. Petrick, E. Reimnitz, D. E. Schulz, J. Thiede, and S. Vlasov)

Magnetostratigraphy of Late Quaternary Arctic Ocean sediments, II: The Lomonosov Ridge, Morris Jesup Rise, and Yermak Plateau (T. Frederichs, N.R. Nowaczyk, and the Arctic '91 Shipboard Scientific Party)

Reworked nannofossils in Quaternary sediments from the central Arctic: implications for paleobiogeography and paleoclimates (G. Gard and A. Crux)

Late Quaternary stratigraphy in the Fram Strait (D. Hebbeln and G. Wefer)

Late Quaternary paleoceanography in the Fram Strait (D. Hebbeln and G. Wefer)

Short-term advections of Atlantic water to the Fram Strait: moisture source for the build-up of the Late Weichselian Barents Sea ice sheet (D. Hebbeln)

230-Thorium and 10-Beryllium stratigraphy of two sediment cores from the Arctic Sea (G. Hentzschel, A. Eisenhauer, A. Mangini, R. Spielhagen, M. Suter, G. Bonani and W. Wölfli)

Physical properties of Late Quaternary central Arctic deep sea sediments: paleoceanographic significance (H. Kassens, D. Mosher, K. Moran, and Arctic '91 Shipboard Scientific Party)

Benthic foraminifera in modern glacial floor sediments of the Barents Sea (S.A. Korsun and I.A. Pogodina)

Sedimentological indicators of sea ice cover in Arctic deep-sea sediments (T. Letzig, H. Lange, and J. Thiede)

The peculiarities of geology and Quaternary palaeogeography of the shelf of Franz Josef Land (G.G. Matishov)

The Arctic Ocean record: key to global change (NAD Nansen Arctic Drilling Program (L. Johnson and Members of the NAD Executive and Science Committees)

Magnetostratigraphy of Late Quaternary Arctic Ocean sediments, I: The Amundsen Basin (N.R. Nowaczyk, T. Frederichs, and the Arctic'91 Shipboard Scientific Party)

A high-resolution, 400,000 year sedimentary record of the Lomonosov Ridge (Central Arctic Ocean) (N.R. Nowaczyk, A. Eisenhauer, T. Frederichs, G. Gard, H. Hubberten, H. Kassens, A. Mangini, N. Nørgaard-Pedersen, R. F. Spielhagen, R. Stein, and the Arctic'91 Shipboard Scientific Party)

Sediments in the Arctic sea ice (D. Nürnberg, D. Dethleff, H. Kassens, T. Letzig, E. Reimnitz, and J. Thiede)

The Laptev Sea polynya as sediment source for the transpolar drift? (E. Reimnitz, D. Dethleff, D. Nürnberg, and Y. P. Savchenko)

Mapping the Arctic Ocean low-salinity surface layer by means of stable isotopes in planktonic foraminifers from surface samples and short sediment cores (R.F. Spielhagen, S.E.I. Köhler, R. Stein, H.W. Hubberten, and the POLARSTERN Shipboard Scientific Party Arctic'91)

Distribution of modern and last glacial maximum sediment facies in the eastern Central Arctic Ocean (R. Stein, H. Grobe, M. Wahsner, and the Arctic'91 Shipboard Scientific Party)

Stable isotope stratigraphy and organic carbon accumulation in the Late Quaternary Central Arctic Ocean (R. Stein, C. Schubert, and the Arctic'91 Shipboard Scientific Party)

On Pleistocene under-glacier flows of thawing waters of the last glaciation in the Arctic Seas sedimentation (G.Tarasov)

The correlation problems of marine and continental oxygen isotope diagrams of the Arctic for the last 40,000 years (Y.K. Vasil'chuk)

2.5 NORWEGIAN-GREENLAND SEAS

Convenors: U. Bleil (Bremen), P. Schäfer (Kiel)
(Thursday/Friday)

Holocene plankton assemblages in the North Atlantic - a comparison of the coccolithophorid-diatom-dinoflagellate-radiolarian association on a south-north-transect (H. Andruleit, A. Baumann, A. Kohly, and A. Schröder)

Contourite sedimentation in the vicinity of a mid-plate volcano in the Greenland Sea (M. Antonow)

Late Quaternary dinoflagellate cyst ecostratigraphy in the northeastern North Atlantic and Norwegian sea (A. Baumann, and J. Matthiessen)

Climatic change in the Norwegian-Greenland Sea and Fram Strait during the last 300,000 years: ice-rafted terrigenous input versus carbonate flux (K.-H. Baumann, B. Jünger, K. Lackschewitz, R.F. Spielhagen, T.C.W. Wolf, and R. Henrich)

Time series studies of ocean properties in the Norwegian-Iceland sea over the past 400.000 years (I. Beyer and E. Jansen)

Seasonal foraminiferal flux in the Fram Strait and Greenland Sea (J. Carstens and G. Wefer)

$\delta^{18}O$ values of *N. pachyderma* tests collected with sediment traps in the Fram Strait and Greenland Sea (J. Carstens and G. Wefer)

Orbital cyclicity in high-latitude sediments: spectral analysis of multi-sensor, core-logging data (J. Chi and J. Mienert)

SFB 313 "environmental change: the northern North Atlantic" (DFG- Special Research Program 313, University of Kiel, Germany)

Paleoceanographic changes in the northeastern part of the Norwegian Sea during the past 50,000 years (T. Dokken and M. Hald)

Oxygen isotope stage 5 in the Norwegian-Greenland-Sea: oceanographic and ecological aspects from isotopic and benthic foraminiferal evidence (H. Erlenkeuser and F. Haake)

Ice-rafting of terrestrial till balls into the Greenland Sea (P. Goldschmidt)

Paleotemperature and productivity variations in the Norwegian-Greenland Sea during the last 20 kyr, an east-west transect (H. Haflidason and H.P. Sejrup)

Surface-water regimes and glaciomarine processes in the Norwegian-Greenland Sea: (i) modern regimes (R. Henrich, P. Goldschmidt, and T. Wagner)

Surface-water regimes and glacio-marine processes in the Norwegian Greenland Sea: (ii) the past 450 ky (R. Henrich, P. Goldschmidt, and T. Wagner)

Organic facies evolution of Neogene and Quaternary sediments from the Norwegian Sea (ODP Leg 104/Vøring Plateau) (J. Hölemann, R. Henrich, and M. Wiesner)

New interpretation possibilities of past ocean circulation and chemistry on the combined use of $\delta^{18}O$ and $\delta^{13}C$ measured on planktonic foraminifers (T. Johannessen, E. Jansen, and A.C. Ravelo)

Variations of $\delta^{18}O$ isotope and carbonate content in the Greenland basin sediments (B. Jünger and H. Erlenkeuser)

Paleoceanographic development of the Greenland, Iceland, and Norwegian Seas through the last 15 ka: the diatom and $\delta^{18}O$ evidence (N.K. Karpuz, E. Jansen, and H. Haflidason)

A high resolution diatom record of the last deglaciation from the SE Norwegian Sea: documentation of rapid climatic changes (N.K. Karpuz, and E. Jansen)

Pleistocene iceberg transportation in the North Atlantic according to data on erratic stone material (G.S. Kharin)

Postglacial plankton and tephra events at the continental margin off northern Norway (S. Locker)

Settling-velocity of sand-size fraction for comparison of Quaternary glacial/interglacial sediments from northern North Atlantic (K. Michels)

Changes in sedimentary facies along the east Greenland continental margin: implications for the glacial/interglacial history of Greenland during Late Quaternary times (S.-I. Nam, H. Grobe, H.-W. Hubberten, and R. Stein)

A 180,000 year magnesium record in *Neogloboquadrina pachyderma* sinistral - a tool for the thermal reconstruction of Norwegian Sea-surface waters (D. Nürnberg)

Thermal evolution of North Atlantic surface water masses over the last 200 ka-geochemical and micropaleontological indications (D. Nürnberg and K.-H. Baumann)

Glacial/interglacial benthic foraminifera in the Norwegian Sea, ODP Site 643 (L. Osterman)

Land-sea correlation of the last 25,000 years of the Svalbard/Barents Sea and East Greenland Margin: preliminary results (PONAM/CLAMD Working group; Anders Elverhøi)

Molecular stratigraphy of mid and high latitude Northeastern Atlantic cores (A. Rosell, P.Merryweather, G.Read, G.Eglinton, J.Villanueva, and J.Grimalt)

Particular flux under melting sea ice in East Greenland Current (M. Saarso)

Living coccolithophore communities in the Norwegian-Greenland Sea and their distribution in surface sediments (C. Samtleben, K.-H. Baumann, and A. Schröder)

$^{230}Th_{ex}$ flux and $^{10}BE/^{230}Th_{ex}$ ratios in sediments from the Norwegian Sea (J.C. Scholten, R. Botz, T. Eisenhauer, H. Paetsch, P. Stoffers, G. Bonani, M. Suter, and W. Wölfi)

Paleo-ecology of benthic foraminifera in Norwegian-Greenland Sea - the past 600,000 years (U. Struck)

Organic matter in pelagic sediments of the Norwegian-Greenland Sea: glacial/interglacial variations and implications to the preservation of marine organic matter (T. Wagner, H. Erlenkeuser, R. Henrich, and M. Wiesner)

Response to climatic changes in the Norwegian Sea: Pleistocene plankton and terrigenous sediment records (ODP-Leg 104, Site 643) (T.C.W. Wolf, K.-H. Baumann, and J. Thiede)

2.6 NORTHERN NORTH ATLANTIC

Convenors: E. Erba (Milano), H. Heinrich (Hamburg)

(Thursday/Friday)

Deep-sea paleocirculation and paleoenvironment over the past 30,000 years in the N.E. Atlantic Ocean: the benthic microfauna record (S. Becquey)

Evidence for massive discharges of icebergs into the glacial North Atlantic (G.Bond, H. Heinrich, S. Huon, W.S. Broecker, L. Labeyrie, J. Andrews, J. McManus, K. Tedesco, R. Jantschik, C. Simet, M. Klas, and C. Clasen)

Distribution of recent benthic foraminifera from the NW Atlantic abyssal plain and continental margin (E.S. Collins, W. Kuhnt, and D.B. Scott)

Sediments of the Iceland-Faroe Ridge: 1. environment-controlled biogenic sediment structures (S. Fu and F. Werner)

Early glacial deposits in Iceland - implications for climatic changes in the North Atlantic (A. Geirsdóttir and J. Eiríksson)

Patterns of ice-rafted detritus in the glacial North Atlantic (40-55°) (F. Grousset, L. Laberyie, J. Sinko, G. Bond, J. Duprat, M. Cremer, and S. Huon)

$\delta^{18}O$-variations in diagenetic sequences from Atlantic sedimentary basins (J. Grützner and J. Mienert)

A comparison of the glacial circulation record of the eastern North Atlantic at oxygen isotope stage 2 and 6 (A. Kuijpers, L. Bornmalm, and K. Winn)

Temperature and salinity history of the last deglaciation and Heinrich ice-rafting events I to IV in the NE Atlantic (M.A. Maslin, N.J. Shackleton, J.-C. Duplessy, and M.Arnold)

Planktic foraminifera as indicators of ocean environments in the NE Atlantic (J.J. Ottens)

Subsidence and sedimentary history south-west of the Faeroe Islands (J. Posewang and Fr. Theilen)

Late Quaternary paleoceanography of the Sohm Abyssal Plain: benthic foraminiferal assemblages, total carbonate and stable isotope evidence (A. Putar-Roberts and D. B. Scott)

Ocean sediment fluxes: spatial and temporal variability in the Atlantic Ocean (J. Thiede, W. Brückmann, W. Brenner, J. Mienert, T.C.W. Wolf, A. Dettmer, and K.U. Schmidt)

Northeastern Atlantic benthic foraminifera during the last 30,000 years (E. Thomas, L. Booth, M. Maslin, and N.J. Shackleton)

Bathymetry of the North Atlantic Ocean between the Charlie-Gibbs and Jan Mayen Fracture Zones during the Tertiary (C. N. Wold)

Greenland-Scotland Ridge subsidence: a possible link to Neogene deep-water circulation patterns and climate change (J.D. Wright and K.G. Miller)

2.7 SOUTHERN OCEAN

Convenors: L. Labeyrie (Gif-sur-Yvette), G. Wefer (Bremen)

(Thursday/Friday)

Quaternary history of the Antarctic Circumpolar Current, its frontal systems and Antarctic sea ice (Atlantic sector) (A. Abelmann, G. Bohrmann, R. Gersonde, H.-W. Hubberten and H.-S. Niebler)

Radiolarian-based transfer functions for the estimation of paleo-environmental parameters in the Southern Ocean (Atlantic Sector) (A. Abelmann)

Radiolarian particle flux in the Southern Ocean (Atlantic Sector) (A. Abelmann)

Paleoceanography and microbiostratigraphy of the Moby Dick Group, Melville Peninsula, Northern King George Island, Western Antarctic (V.S. Abreu, R. Savini and S. Barrocas)

Sub-Antarctic diatoms of core PS1752-1 (Atlantic sector of Southern Ocean - ANT viii/3 AWI) (M.A. Bárcena, R. Gersonde, and J.A. Flores)

Reconstruction of Late Quaternary bottom water circulation in the eastern South Atlantic: stable isotopes in benthic foraminifera (T. Bickert and G. Wefer)

Biogeochemical cycle of barium in the South Atlantic (C.C. Brahms, G. Bohrmann, M. Schlüter, and M. Rutgers v.d. Loeff)

Paleoceanographic and paleoclimatic evolution in the Weddell Sea (Antarctica) during the Middle Eocene-Late Oligocene, from coarse fraction and clay mineral data (L. Diester-Haass, C. Robert, and H. Chamley)

A high resolution record of opal, carbonate and terrigenous fluxes in subantarctic S.E. Indian Ocean during the last 40,000 years (R. François, M.P. Bacon, M.A. Altabet, and L.D. Labeyrie)

Sea ice variability and paleoproductivity changes in the Late Quaternary Southern Ocean (R. Gersonde, G. Bohrmann, A. Abelmann, U. Zielinski and A. Barcena)

Diatom particle flux in the Southern Ocean (Atlantic sector) (R. Gersonde and U. Zielinski)

Discrete baryte particles and barium as tracers of paleoproductivity in South Atlantic sediments (F. X. Gingele)

Southern Ocean origin of biserial planktonic foraminifera (*Chiloguembelina* and *Zeauvigerina*) below the Cretaceous/Tertiary boundary (B. Huber and A. Boersma)

The development of Antarctic diatom flora in the Cenozoic (G. Kazarina and V. Mukhina)

The Southern Ocean role in glaciation cycles: inferences from a study of core MD 88-770 (L.D. Labeyrie, M. Labracherie, N. Gorfti, J.J. Pichon, W. Howard, J. Duprat, and G. Bareille)

Paleoceanography of the subantarctic Indian Ocean (M. Labracherie, L. Labeyrie G. Bareille, M. Vautravers, J. Duprat, M. Caralp, and J.J. Pichon)

The stable isotopic composition of glacial Antarctic Intermediate Water (J. Lynch-Stieglitz, R. Fairbanks, and C. Charles)

Late Quaternary palaeoceanographic reconstruction of the southern Tasman Sea, southwest Pacific (J.I. Martínez, S. Nees, P. De Deckker, and M.A. Ayress)

Glaciology and oceanography in the southern Weddell Sea since the last glacial maximum (M. Melles)

Planktonic foraminifers as tracers of ocean currents in the eastern South Atlantic (H. Oberhänsli, C. Bénier, G. Meinecke, H. Schmidt, R. Schneider, and G. Wefer)

Late Middle Eocene bottom water event in the South Atlantic (H. Oberhänsli, and E. Müller-Merz)

Advective transport of particles in the Antarctic Circumpolar Current, deduced from discrepancy between trap flux and sediment accumulation of 210PB (M.M. Rutgers van der Loeff)

The diatom record from beneath the West Antarctic ice sheet and the global proxy perspective (R.P. Scherer)

Changes in the Southern Ocean over the last 22 ky: a view from the Chatham Rise (E.L. Sikes, H.L. Neil and S.D. Nodder)

Calibration of long-chain alkenone unsaturation ratios for paleotemperature estimation in cold polar waters (E. L. Sikes and J. K. Volkman)

Records of Antarctic temperature, atmosphereic CO_2 and ice volume during the last deglaciation (T. Sowers, M. Bender, and J-M. Barnola)

Acoustic stratigraphy of Maud Rise sediments -a digital Parasound echosounder survey at ODP Sites 689 and 690 (V. Spieß)

Chronology of late Neogene Antarctic ice sheet variation: glaciation; deglaciation and associated sea level signatures (G.S. Wilson)

Diatoms - tools for Quaternary paleoenvironmental reconstructions in the Southern Ocean (U. Zielinski)

2.8 OCEAN-ATMOSPHERE MODELING

Convenor: K. Herterich (Bremen), D. Seidov (Moscow)

(Thursday/Friday)

Phanerozoic climate modes and their origins in the carbon cycle (L.A. Frakes, J.E. Francis, and J.I. Syktus)

Towards modeling the paleocirculation and sedimentation of the northern North Atlantic (B.J. Haupt, C. Schäfer-Neth, and K. Stattegger)

A model study of the glacial ocean (S. Hovine and T. Fichefet)

Estimated CO_2 levels from photosynthetic ^{13}C fractionation in the central equatorial Pacific over the last 255,000 years (J.P. Jasper, F.G. Prahl, A.C. Mix, and J.M. Hayes)

Atmospheric forcing on sea surface water (A. Juillet-Leclerc, L.D. Labeyrie, and J. Jouzel)

Ocean-atmosphere CO_2 exchange in the last glacial to interglacial: the coral hypothesis (K. Kato)

Cold surface ocean ventilation and its effect on atmospheric CO_2 (R. Keir)

The effect of changing continental weathering rates on atmospheric CO_2 over glacial to interglacial time scale (G. Munhoven and L.M. François) *NATO ARW abstract*

Glacial to interglacial, basin to shelf partitioning of $CaCO_3$ and its effect on atmospheric CO_2 (B.N. Opdyke and J.C.G. Walker)

Dissolved organic matter and the glacial-interglacial pCO_2 problem (D. Paillard)

A dynamic model of carbon cycling in upwelling cells along coastal margins (R. M. Ross, M. Sarnthein, and K. Winn)

Geothermal heat - a trigger of ocean circulation (S. Sakai and T. Kimoto)

Numerical model for the ocean paleocirculation studies (D. Seidov)

Toward a better understanding of the North Atlantic response to the meltwater event near 13.6 ka - a numerical ocean circulation model (D. Seidov, I. Yushina, M. Sarnthein, and K. Stattegger)

Organic carbon accumulation rates in the Holocene and glacial Arabian Sea: implications for atmospheric CO_2 variations (F. Sirocko and V. Ittekkot)

Transient behavior of the deep ocean circulation and tracer fields during the Younger Dryas (D.G. Wright, T.F. Stocker, and W.S. Broecker)

2.9 PALEOCEANOGRAPHY OF THE EASTERN EQUATORIAL PACIFIC: THE ODP LEG 138 RECORD

Convenors: J. Farrell (Providence), N. Pisias (Corvallis)

(Thursday/Friday)

Middle Miocene climatic fluctuations in the eastern Equatorial Pacific Ocean at ODP Site 845 (Leg 138) (L. Beaufort and E. Vincent)

Preliminary results of a study of the seismic stratigraphy of the Eastern Equatorial Pacific (S.F. Bloomer, L.A. Mayer and Leg 138 Shipboard Scientific Party)

Population counts of planktonic foraminifera at four equatorial Pacific sites (B. Chaisson)

Alkenone sea-surface temperatures and productivity at ODP Site 846 (Eastern Equatorial Pacific) in the Late Quaternary (K.-C. Emeis, D. Schulz-Bull, and H. Doose)

Links between nannofossil preservation and carbonate sedimentation in Neogene sediments from the Eastern Equatorial Pacific (ODP Leg 138) (J.W. Farrell, I. Raffi, J.-A. Flores, and K.C. Emeis)

Late Pleistocene stable isotope records from surface ocean and thermocline dwelling planktic foraminifera: ODP Site 847, Eastern Equatorial Pacific (J.W. Farrell, D. Murray, and S. Clemens)

Phosphorus accumulation rates in the Eastern Equatorial Pacific from Miocene to present: results from Sites 844, 846, and 851, ODP Leg 138 (G. Filippelli and M. Delaney)

Calcareous nannofossil high resolution quantitative analyses in the Pliocene of ODP Sites 849 and 852 (Leg 138, Eastern Equatorial Pacific) (J.A. Flores, I. Raffi and F.J. Sierro)

Spatial and temporal variability of late Neogene equatorial Pacific carbonate: ODP Leg 138 (T. Hagelberg, N. Shackleton, L. Mayer, N. Pisias, A. Mix, and ODP Leg 138 Shipboard Party)

Refinement of a high-resolution, continuous sedimentary section for the study of equatorial Pacific paleoceanography: ODP Leg 138 (T. Hagelberg, A. Mix, N. Pisias, N. Shackleton, T. Janecek, and the Leg 138 Party)

Physical properties of sediments from the equatorial East Pacific (ODP Leg 138) (P.Holler, D.C.Kim, K. MacKillop, and L. Meynadier)

Neogene atmospheric circulation intensity and climatic variability recorded by eolian sediments from Leg 138, Eastern Equatorial Pacific (S. A. Hovan)

Pelagic laminated diatom ooze in the Eastern Equatorial Pacific: a record of peak Neogene paleoproductivity (A.E.S. Kemp and J.G. Baldauf)

The reflection of the Pacific east equatorial zone paleoceanographic changes in the chemical composition of Miocene-Quaternary sediments (on ODP Leg 138 data) (M.A. Levitan)

3-d visualization of evolutionary spectra of Leg 138 carbonate records (L.A. Mayer, N.J. Shackleton, T. Hagelberg, N. Pisias, C. Ware, K. Marinelli, and the ODP Leg 138 Scientific Party)

Benthic foraminiferal $\delta^{18}O$ and $\delta^{13}C$ from ODP Leg 138 Site 849, 0-3 ma: Implications for Panama Basin paleo-productivity and global ocean circulation (A.C. Mix, N.J. Shackleton, N. Pisias, J. Wilson, A. Morey, W. Rugh, T. Hagelberg, and the ODP Leg 138 Shipboard Party)

Automated color reflectance spectroscopy for rapid characterization of deep-sea sediments: calibration with lithologic data on ODP Leg 138 (A.C. Mix, T. Janecek, N. Pisias, W. Rugh, T. Hagelberg, and the ODP Leg 138 Shipboard Party)

Biogenic fluxes at ODP Site 847, eastern tropical Pacific during the past 3 million years (D.W. Murray and J.W. Farrell)

Temporal response of the east Pacific carbonate system to orbital forcing: evidence from site 849 Leg 138 (N Pisias, L. Mayer, N. Shackleton, T. Hagelberg, A. Mix, and ODP Leg 138 Shipboard Party)

Miocene to Pleistocene calcareous nannofossils from the Eastern Equatorial Pacific Ocean (ODP Leg 138) (I. Raffi and J.A. Flores)

ODP Site 851 - Eastern Equatorial Pacific isotopic records of surface circulation changes (A.C. Ravelo and N.J. Shackleton)

Miocene magnetostratigraphic results from Ocean Drilling Program Leg 138: new events refine the geomagnetic polarity time scale (D.A. Schneider)

An astronomically calibrated Pliocene time scale based on Leg 138 grape density records (N.J. Shackleton, S.J. Crowhurst, N. Pisias, T. Hagelberg, D. Schneider, A. Mix, and ODP Leg 138 Shipboard Party)

Oxygen isotope stratigraphy of the Pliocene in ODP Site 846 (N.J. Shackleton, M.A. Hall, L. Mayer, N. Pisias, and ODP Leg 138 Shipboard Party)

ABSTRACTS

in alphabetical order of first authors' names

DIATOM ASSEMBLAGES IN ARCTIC SEA ICE - INDICATOR FOR ICE DRIFT PATHWAYS

A. Abelmann (Alfred Wegener Institute, Bremerhaven, Germany)

During RV "Polarstern" expeditions ARK IV/3 and ARK VI/1 well-preserved diatom assemblages were recovered from particle-laden sea ice collected from the western Barents Shelf, and the Arctic Ocean between Svalbard (81°N) and the Nansen-Gakkel Ridge (86°N). Distinct variations in the abundance pattern and species composition of diatoms were found north and south of ca. 83°N.

Highest diatom concentrations were encountered in multi-year sea ice in the core of the Transpolar Drift Stream between 83° and 86° N. In this area diatom assemblages are dominated by marine-brackish benthic species. Apparently, these assemblages originate in shelf waters north and east of Siberia, where they are incorporated into the sea ice as a bottom ice assemblage. During the transport of the ice floes across the Eurasian Basin within the Transpolar Drift Stream, seasonal basal freezing and surface melting processes may have led to an accumulation of diatoms at the sea-ice surface.

South of ca. 83° N the sea ice samples contained significantly lower numbers of diatoms, dominated by fresh-water taxa. Between 83°N and 81°N these assemblages are dominated by planktonic freshwater taxa, but on the Barents Sea Shelf, east of Svalbard, significant numbers of benthic fresh-water taxa and benthic marine-brackish species also are found. This ice may originate in the Barents Sea and/or the Kara Sea, which receive a large influx of fresh water by the Siberian rivers Ob and Yenesei.

It can be concluded that the distribution pattern of diatoms in particle-laden sea ice can be used for identification of ice drift pathways.

QUATERNARY HISTORY OF THE ANTARCTIC CIRCUMPOLAR CURRENT, ITS FRONTAL SYSTEMS AND ANTARCTIC SEA ICE (ATLANTIC SECTOR)

A. Abelmann (Alfred Wegener Institute, Bremerhaven, Germany), G. Bohrmann, R. Gersonde, H.-W. Hubberten, and H.-S. Niebler

The presented results of late Quaternary Antarctic Circumpolar Current (ACC) history and sea-ice distribution are based on quantitative analysis of siliceous and calcareous microfossil assemblages, and isotopic and biogenic opal measurements in selected well-dated sediment cores from a N-S transect across the ACC between 40° and 56°S. First results focus on a comparison of the present-day situation with three time intervals: the climatic optima at 125 ka (stage 5.5) and at 9 ka (Holocene climatic optimum in the Southern Hemisphere), and the last glacial maximum (LGM) at 18 ka.

During climatic optima a relative warming of the surface water in the area of the polar frontal zone and the adjacent Antarctic zone is indicated by the southward migration of Sub-Antarctic radiolarians. The lack of sea-ice diatoms shows a significant southward shift of the winter sea-ice boundary, while opal measurements indicate a southward extension of the opal belt.

During the LGM, radiolarian taxa that dwell today in the polar frontal zone migrated northward to the area of the present Sub-Antarctic front. The winter sea-ice boundary was located north of its present position. Our data do not show a northward shift of the high-accumulation opal belt established during the climatic optima south of the present polar front. However, the pattern of the productivity proxies indicate a relative increase in productivity during glacial time periods in the area north of the polar front.

Similiar to the findings in the southern zones of the ACC, the analysis of planktonic foraminiferal assemblages in a core located under the subtropical front gives no evidence for significant glacial/interglacial latitudinal shifts of the subtropical front.
The scenario of rather stable location of the frontal systems is also supported by the isotopic record. The difference between Holocene (core top) and LGM $\delta^{18}O$ values is notably constant on a latitudinal transect across the ACC.

RADIOLARIAN-BASED,TRANSFER FUNCTIONS FOR THE ESTIMATION OF PALEO-ENVIRONMENTAL PARAMETERS IN THE SOUTHERN OCEAN (ATLANTIC SECTOR)

A. Abelmann (Alfred Wegener Institute, Bremerhaven, Germany)

The radiolarian data set of 60 taxa in 35 undisturbed surface sediment samples collected with a multicorer in the area of the Antarctic Circumpolar Current (ACC, eastern Atlantic sector) was resolved by the Q-mode factor analysis into four varimax factors, accounting for 94.45% of the distributional variance of the species included. Each factor represents a faunal assemblage which shows a close spatial correlation to present-day hydrography (e.g. the zonal bands of the ACC).

A multivariate regression analysis was used to derive a transfer function for relating the four varimax factors to surface-water temperature, salinity, and phosphate concentration. Temperatures and salinities used represent mean austral summer values (December to March). These values were chosen because sediment-trap experiments indicate that export production in the Southern Ocean is restricted to the austral summer.

The transfer functions for summer surface temperature, salinity, and phosphate values have high correlation coefficients and low standard errors of estimates (temperature: 1.28°C; salinity: 0.08‰; phosphate concentration: 0.22 µmol/l). The validity of the transfer functions can be judged by the geographical analysis of residuals, which shows no obvious geographical distribution pattern.

Because of the low standard errors of the derived transfer functions for summer surface temperature, salinity and phosphate concentrations, this method provides a good tool for down-core reconstruction of paleoceanographic parameters in Quaternary sediments in the Southern Ocean.

RADIOLARIAN PARTICLE FLUX IN THE SOUTHERN OCEAN (ATLANTIC SECTOR)

A. Abelmann (Alfred Wegener Institute , Bremerhaven, Germany)

The study of the flux pattern of radiolarians provides information on productivity, ecology, dissolution processes, vertical and horizontal transport of radiolarians in the Antarctic Ocean. Data on radiolarian particle flux were gathered with sediment traps moored at six sites located in the Drake Passage, Powell Basin, Bransfield Strait, NW Weddell Sea, SE Weddell Sea (west of Maud Rise), and at the polar front. The data were also compared to those obtained by the study of radiolarian assemblages preserved in the surface sediments.

The annual radiolarian particle flux is characterized by significant seasonal and inter-annual variations. Flux pulses, accounting for 80 to 90% of

the total annual radiolarian flux occur during austral summer, with a duration ranging between ca. 2 and 9 weeks. Inter-annual differences in the radiolarian flux range over a factor of ten.

The sedimentation of radiolarians (protozooplankton) is more or less synchronous to the total mass flux. This pattern can partly be explained by scavenging of the radiolarians during phytoplankton mass sedimentation, which is controlled by the grazing of metazooplankton.

Significant lateral transport of resuspended radiolarian particles, which was observed in the bottom water layer in regions surrounded by shelf areas (Bransfield Strait) and in the vicinity of topographic elevations (Maud Rise) indicates the significance of the redistribution of biogenic silica in these regions.

The composition of the radiolarian assemblages at the different mooring stations is well correlated to the environmental conditions and water masses. The radiolarian flux is in the range of the radiolarian burial rates calculated at the different sites. The composition of the trapped assemblages is well reflected in the surface sediment record, except for the phaeodarian signal. Thus, the sediment trap studies support the good significance of radiolarians for paleoenvironmental reconstructions.

PALEOCEANOGRAPHY AND MICROBIOSTRATIGRAPHY OF THE MOBY DICK GROUP, MELVILLE PENINSULA, NORTHERN KING GEORGE ISLAND, WESTERN ANTARCTIC

V.S. Abreu (Petrobrás-Cenpes, Cidade Universitaria, Rio de Janeiro, Brazil), R. Savini, and S. Barrocas

Foraminiferal studies were carried out from outcrop sections of the Destruction Bay and Cape Melville Formations, Moby Dick Group, in the Melville Peninsula, northern King George Island, western Antarctic. The Moby Dick Group is composed of rocks contemporaneous to the initial opening phases of the Bransfield Strait and to the tectonic events that culminated in the development of the Scotia Arch and the opening of the Drake Passage. Planktonic foraminifera, recorded for the first time in these rocks, suggest a late Oligocene age for this succession. The benthonic foraminifera indicate a shallow neritic depositional environment for the Destruction Bay Formation strata (lower part), and deep neritic to upper bathyal environments for the Cape Melville Formation rocks (upper part), in a characteristic, transgressive sequence. All these rocks were accumulated in environments shallower than the calcium carbonate compensation depth (CCD) of the time, as suggested by the absence of microfossil dissolution levels. The occurrence of sub-Antarctic to temperate foraminiferal assemblages indicates that these rocks were deposited before the thermal isolation of the Antarctic region, probably during the early opening stages of the Drake Passage in the late Oligocene. Therefore, the deposits of the Moby Dick Group are the geological record of the early drifting stages between Antarctic and the South American continental plates. They represent a part of the evolution of the continental margins of the Drake Sea and the Brafield Strait.

GRAIN-SIZE VARIATION IN NORTHEAST ATLANTIC SEDIMENTS: RESPONSE TO DEEP CIRCULATION

B. Afergan (Dept. of Earth Sciences, Univ. of Cambridge, UK) and I.N. McCave

Grain-size variation and, in particular, the mean size of the non-carbonate silt fraction, has been used by many workers as a proxy of current intensity in the pelagic marine record. The signal may be obscured in mid- to high latitudes by the addition of ice-rafted material during glacials. However, this input can be recognized in magnetic susceptibility records, and is reflected in the non-carbonate flux data and silt percentages.

Detailed grain-size analysis has been carried out on a suite of kasten cores from the northeast Atlantic. The cores are from a north-south transect across the East Thulean Rise to the Rockall Plateau, and are well placed to record changes in intensity of currents over a range of depths. The results reveal variations in silt mean which is independent of terrigenous input flux, and may be attributed to current fluctuation during the last 25,000 years. The pattern of grain-size variation at sites influenced primarily by North Atlantic deep water differs markedly from that at nearby, deeper sites which are reached by Antarctic bottom water currents, and from shallower, intermediate water-influenced sites on the Rockall Bank. Dating for the cores is based on correlation with an AMS-dated member of the suite, and the timing of changes in relative current intensity has important implications for the debate on the influence of ocean circulation modes upon rapid climatic change.

LATE QUATERNARY PALEOCEANOGRAPHY OF THE BANDA SEA

S.M. Ahmad (National Geophysical Research Institute, Hyderabad, India), L.D. Labeyrie, and F. Guichard

Stable isotope records of benthic (*Uvigerina* and *Cibicides* species) and planktonic *(G. ruber)* foraminifera recovered from a deep-sea core in the Banda Sea were obtained to understand surface and deep-water hydrography for the last climatic cycle. The benthic record exhibits depletion of about 0.3‰ for the last glacial maxima (LGM) relative to the Holocene. Still higher depletion of $\delta^{13}C$ during penultimate full glaciation (stage 6) is attributed to the increased residence time of the Banda deep water. Variations in the $\delta^{13}C$ of planktonic foraminifera for the last climatic cycle are due to the local changes in monsoonal upwelling. The increase in the alkalinity and deepening of the lysocline has resulted in the high carbonate content during glacial periods, as reported in the North Pacific also.

$\delta^{15}N$ CONSTRAINTS ON THE UTILIZATION OF NUTRIENTS IN THE OCEANS: APPLICATION FOR PALEOCEANOGRAPHIC PROBLEMS

M.A. Altabet (Woods Hole Oceanographic Institution, Woods Hole, MA , USA), R. François, and W.B. Curry

Glacial/interglacial variations in atmospheric pCO_2 and associated climate change may have been brought about by changes in surface ocean nutrient biogeochemistry. Many of the sedimentary proxies employed to date, however, cannot distinguish between effects brought about by circulation vs. biological

productivity. Moreover, few studies have focused on past changes in nitrogen biogeochemistry despite this element being a major phytoplankton nutrient.

In the near-surface ocean, the natural abundance of ^{15}N is significantly affected by NO_3^- utilization as a result of isotopic discrimination during phytoplankton uptake and recent studies in the contemporary ocean have shown a strong relationship between degree of NO_3^- depletion and the $\delta^{15}N$ of near-surface POM. In the temperate N. Atlantic, $\delta^{15}N$ values increased by 13 ‰ as NO_3 was depleted during the spring bloom. In the Equatorial Pacific and Southern Ocean, strong latitudinal gradients in δ^{15} (range ~10 ‰) mirror the well-known latitudinal gradients in surface (NO_3^-) found in these regions. Analysis of core tops show similar latitudinal variations in sedimentary $\delta^{15}N$ demonstrating that the surface isotopic signal is transmitted to and preserved in the sediments. Moreover, secondary features in surface properties such as the asymmetrical distribution of surface (NO_3^-) about the equator is reflected in the distribution of sedimentary $\delta^{15}N$, giving further confidence in its use as a recorder for past nutrient utilization. In the Southern Ocean, though, sedimentary $\delta^{15}N$ are elevated relative to surface values suggesting diagenetic influences that need to be further investigated.

Sequences from the last glacial maximum exhibit a southward shift in the latitudinal $\delta^{15}N$ gradient in the Southern Ocean. Assuming a uniform diagenetic effect over this region, Subantarctic waters had a high degree of nutrient utilization during the last glacial maximum. Our data, however, do not support the massive nutrient depletion hypothesized for the glacial Southern Ocean.

RECONSTRUCTING PAST OCEAN TEMPERATURE USING FORAMINIFER FOSSIL PLANKTON: ADVANTAGES OF RESPONSE SURFACE METHODOLOGY

D.M. Anderson (NOAA Paleoclimatology Program, Boulder, CO, USA), R.C. Thunell, M. Qingmin, and K.H. Anderson

One of the greatest potential problems with temperature estimates derived from foraminifer species composition is that they fail to include the effect of dissolution that alters the sediment assemblage by preferentially removing some species and increasing the dominance of others. To improve the estimates, we applied response surface methodology to examine the combined influence of temperature and dissolution on species abundance in sediments from the Pacific Ocean. Our approach thus includes the influence of ecological (temperature) and depositional (dissolution) variables on the sediment assemblage. To construct response surfaces, we plotted species abundance (%) as a function of mean annual Sea Surface Temperature (SST) and water depth, using depth as a proxy for basin-average carbonate-ion saturation. All species show distinct variations in abundance as a function of SST, and several reveal equally large changes as a function of depth. Using the response surfaces defined by the modern core-top samples, we estimated SST and depth for the core-top sample set and calculated the fit between estimated and observed SST ($n=498$, $r^2= 0.84$, std. error 2.5 degrees C). We applied the method to a suite of cores from the Sulu Sea in the western Pacific to estimate SST at the last glacial maximum. Both shallow and deep sites indicate SSTs 3 degrees C colder at the LGM, with little change in dissolution at the shallow sites. In contrast, the recontructed depth of the deep site was much shallower at the LGM, indicative of better preservation. Other methods yielded warmer SSTs for the deep samples, probably an artifact of the change in preservation. In this case, the method successfully separates the influence of SST and dissolution

on the faunal composition of the deep, dissolved samples. Another advantage of the method is that it produces dissolution estimates from each sample, providing information on deep ocean chemistry as well as surface ocean temperature.

HOLOCENE PLANKTON ASSEMBLAGES IN THE NORTH ATLANTIC: A COMPARISON OF THE COCCOLITHOPHORID-DIATOM-DINOFLAGELLATE-RADIOLARIAN ASSOCIATION ON A SOUTH-NORTH TRANSECT

H. Andruleit (Special Research Project 313, Kiel, Germany),
A. Baumann, A. Kohly, and A. Schröder

The plankton assemblages comprising coccolithophorids, diatoms, dinoflagellates, and radiolarians have been investigated in five box/piston cores of late Pleistocene to Holocene age. The cores are located on a transect from Rockall Plateau to west off the Barents Shelf following the main route of the North Atlantic drift and the Norwegian current.

An identical set of samples has been used to define the temporal and spatial distribution of the different groups in order to evaluate changes in the paleo-environment since Termination I.

The four groups are compared to study the environmental parameters of the coexistence and syn-ecology of plankton communities in a pelagic realm. Thus, the recent association and the assemblages in the sediments are considered synoptically to obtain a most complete record of their common development.

Variations in accordance to latitude and core depth can be seen at all four groups reflecting environmental changes. Absolute abundancies and diversities show similar trends in the northern part of the transect, whereas in the south the distribution patterns are more complicated.

HYDROCARBON GAS PLUMES AT THE BOTTOM OF THE OKHOTSK AND JAPAN SEAS

V. Anikiev (Pacific Oceanological Institute, Far Eastern Branch, Academy of Sciences, Vladivostok, Russia) and A. Obshirov

Spatial and temporal variations in gas concentrations in the near-bottom layer of the Okhotsk and Japan Seas have been observed for a number of years. These observations revealed three anomalous features characterized by:

1. Sound dissipative plumes on echosound records;
2. Anomalous increase of methane in the near-bottom water by a factor of 10 to 100;
3. Increased concentration of ethane and propane.

In the Sea of Japan the area with such characteristics is located 50 km southward of Wonsan Harbor; there, at the depth of 120 m, oil and gas deposits with a thickness of 4000 m may occur.

In the Sea of Okhotsk two underwater sources of hydrocarbon gases were found , they are associated with:

1. Oil-bearing basins on the north-western shelf of Sakhalin Island; the thickness of the basin is more than 6000 m. Gas plumes in the area are found at 160 m and 700 m of water depths;

2. Volcanic active structure off Paramushir Island (Kuril Isles) and overlying sedimentary basin, located in 800 m of water depth.

In the sediments of both basins in the Sea of Okhotsk, solid methane gas hydrates were found.

The observations revealed that the intensity of the underwater gas plumes varies with time, probably, due to the variations in seismic activity of the area.

The supposition is made that significant quantities of methane may emanate into the atmosphere under different hydro-meteorological conditions.

CONTOURITE SEDIMENTATION IN THE VICINITY OF A MID-PLATE VOLCANO IN THE GREENLAND SEA

M. Antonow (Institute of Geology, Mining Academy, Freiberg, Germany)

The Vesterisbanken Seamount is situated in the south-eastern part of the Greenland Basin.

Patterns of morphology and sediment distribution have been investigated by Hempel et al. (1991). Seismic reflection profiles indicate a volcanic activity in this area reaching into sub-recent or even recent times.

Surface samples and cores from R/V "Polarstern" cruise ARK VII/1 in 1990 contain distinct volcanic ash layers intercalated to pelagic clastic sediments.

These sediments are characterized by granular variations, changes in composition of coarse fraction (biogenic and siliciclastic components) according to different processes of erosion, transport, and sedimentation. Varying abundance of ice-rafted debris document an, at least seasonal, influence of extended sea ice or drifting icebergs near Vesterisbanken.

X-ray radiographs of all core sections dominantly show sequences of rhythmically bedded silty clay, clayey silt, and sometimes silty sand. These units are usually parallel-bedded and show a thinning upward. Fine and thicker lamination or thin bedding with gradational boundaries can be recognized in the sediment. Primary sedimentary structures are often disturbed by bioturbation of different degree. The effects of lamination are interpreted as the result of short-term fluctuations in sediment supply and erosion by contour currents near the bottom region of Vesterisbanken. Contourites may widely occur along the East Greenland continental slope.

An influence of sporadic subaqueous mass flows due to topography and seismic activity of the area surrounding the seamount seems possible.

BIOMARKERS AND CARBON ISOTOPES IN ORGANIC CARBON-RICH SEDIMENTS. BIOLOGIC RESPONSE OF A MODERN LAKE TO ENVIRONMENTAL CHANGES

D. Ariztegui (Geologisches Institut, ETH-Zentrum, Zürich, Switzerland), J.A. McKenzie, and P. Farrimond

The upwelling of cold, nutrient-rich waters onto continental shelves causes high productivity and leads to the formation of organic carbon-rich sediments. The biomarker approach has been extensively used to assess these paleoenvironments in the sedimentary record, but the finding of specific markers to distinguish upwelling areas from other regions of high productivity remains problematic. The isotopic and geochemical study of the organic matter composition of well-defined recent sediments, such as in modern eutrophic lakes, can aid in distinguishing different depositional settings and in evaluating the factors that may have produced the variations in $\delta^{13}C_{(OM)}$ values and associated biomarkers observed in the geological record.

The alpine Lake St. Moritz in SE Switzerland, contains a Holocene laminated sequence composed of organic carbon-rich siliciclastic sediments. Variations in the organic content (%TOC) through the sequence reflect the degree of water-column anoxia and sedimentation rate. A recent eutrophication of the lake over the last l00 years has resulted in the production of varved sapropels. These annually laminated carbon-rich sediments provide an analogue for the earlier laminated sediments recovered in the sequence and can be used to test the sensitivity of the different organic compounds to changes in the trophic state of the system. Biomarker data, obtained by gas chromatography of total sediment extracts, show downhole fluctuations in lipid abundance and molecular distributions, which are interpreted as a record of changing primary productivity and/or preservation. Rock-Eval analyses, elemental ratios, and pigment studies, as well as the carbon isotope stratigraphy of Lake St. Moritz, show changes consisten with this interpretation.

The study of carbon-isotope and organic geochemical cycles in Lake St. Moritz has demonstrated that sedimentary organic matter is very sensitive to environmental changes. Such lake studies can produce valuable paleoenvironmental information regarding past biological assemblages an depositional conditions, as well as provide new proxies for determining the paleotrophic state of an aqueous system.

LATE-GLACIAL SHELF BIOSTRATIGRAPHY. POTENTIALS AND PROBLEMS

W.E.N. Austin (Dept. of Geology, Univ. of Bergen, Norway)

Increasingly, the search for high resolution sedimentary records of the Late-glacial period will bring palaeoceanographers to the continental margins and onto the shelf seas. Here I present detailed foraminiferal records (benthic and planktic) which document the pattern and timing of deglaciation within shallow water (ca. 150 m.) British Geological Survey vibrocores from the Hebridean Shelf of N.W. Scotland, U.K.

The climatostratigraphic schemes developed are placed within a chronostratigraphic framework, supported by AMS ^{14}C dates and peaks of volcanic shards correlated to known Icelandic eruptions from this period. Reconstructions of both local palaeo-environments (biofacies) and general patterns of changing ocean-climate are possible; these confirm the established oceanic records for this period. Measurements of stable isotopes (D. Kroon, University of Edinburgh) from one of the cores (VE 57/-09/46) with nearly 5 m of sediment representing the Younger Dryas are presented.

It is concluded that there is considerable potential for palaeoceanographic study at such sites, but only after certain aspects of the complex Late-glacial evolution have been resolved through biofacies analysis; examples are given which illustrate the problems.

MICROPALEONTOLOGY OF HYDROTHERMAL VENTS IN THE GUAYMAS BASIN, GULF OF CALIFORNIA, MEXICO

A. Ayala-Lopéz (Inst. de Ciencias del Mar y Limnología, UNAM. Mexico, D.F., Mexico)

A micropaleontologic study of 40 sedimentary samples from a hydrothermal region, in the Guaymas Basin, Gulf of California, Mexico, was carried out to describe microenvironments. These microenvironments were enhanced through a mathematical analysis of the benthic biocoenosis and thanatocoenosis. The results of such analysis were correlated with a gross biogeography of diatoms, radiolarians, planktonic foraminifers and ostracods, through a "graphic-multivariate analysis," and a better picture of the "hydrothermal microenvironments" was defined.

The microenvironments defined are: 1) the "Hydrothermal environment", in which the benthic foraminifera *Bulimina mexicana* and *Cassidulina* sp. cf. *C. subglobosa* are able to live together with the mollusk *Calyptogena pacifica*; 2) the "Bacterial environment," in which *Trochamina* sp. and *Cornuspira* sp. are characteristic, and 3) the "Cool environment," further out from the direct hydrothermal influence, in which the benthic foraminifera *Bulimina spinosa*, *Cibicides* sp. and *Bolivina seminuda* are important.

All these benthic foraminiferal assemblages are different from other assemblages which live in the Guaymas Basin, but do not have any hydrothermal influence. In this environment, *Uvigerina peregrina* and *Buluminella tenuata* are common.

Analysis of sub-bottom samples shows the same behavior as superficial samples: the more drastic environmental conditions for the survival and preservation of microfauna are those of the "Hydrothermal" microenvironment, then the "Bacterial" and, finally, the "Cool."

CENOZOIC PALEOCEANOGRAPHY BASED ON MICROPALEONTOLOGICAL DATA: METHODS AND RESULTS

M.S. Barash (P.P. Shirshov Institute of Oceanology, Academy of Sciences, Moscow, Russia)

In the P.P. Shirshov Institute of Oceanology, the paleoceanographical reconstructions based on micropaleontological data were developed from the early 60's. The methods were based on dependence of the microfossil assemblage distribution in the surface sediments on the environmental conditions mainly on the water temperature. The species were divided into climatic groups (polar, subpolar, temperate, subtropical, tropical, equatorial) according to their highest percentage concentrations - areals, etc. Ratios of these groups in the fossil complexes reflect water temperatures. Using planktonic foraminifera for most characteristic Late Quaternary time levels (about 6, 18, 40, 70, 125 th.y.BP) surface water average annual paleotemperatures for the world ocean, or for its large regions were reconstructed. The results are basically similar to those of the CLIMAP Project. The most important difference from the latter is cooling throughout the whole ocean surface during the last glaciation maximum revealed by our study. Based on the paleotemperature fields, the climatic zonality, paleocurrents, surface-water masses, main hydrological gyres, frontal zones, upwelling activity, current velocity and temperatures at several water depth levels are reconstructed. The same method is elaborated on Radiolaria.

Using ratios between climatic groups of planktic foraminifera, calcareous nannoplankton and diatoms, we reconstructed the positions of biogeographical and climatic zones for some Paleogene and Neogene time slices. The shifts of the zonal boundaries show warming and cooling intervals basically similar to results of other investigators. The most important finding is that climatic changes are sometimes metachronos or even opposite in the different regions, in particular on the high and low latitudes.

SUB-ANTARCTIC DIATOMS OF CORE PS1752-I (ATLANTIC SECTOR OF SOUTHERN OCEAN - ANT VIII/3 AWI)

M.A. Bárcena (Universidad de Salamanca, Spain), R. Gersonde, and J.A. Flores

Quantitative analyses of diatoms were carried out on high resolution sampling of upper Pleistocene and Holocene sediments from hole PS1752-I (Expedition ANT VIII/3, AWI). The combination of biostratigraphic and ecostratigraphic methods indicates that this core contains a rather continuous section covering the last 670 Kyr. The derivative sedimentation rates are ca. 1.0 cm/kyr for the last 300 kyr, and ca. 1.4 cm/kyr for the oldest interval (300 to 670 kyr).

The diatom assemblage is dominated by *Nitzschia kerguelensis*. Increases in that taxon, together with warm-water related taxa, are in agreement with warm time intervals. Relative abundance peaks of *Chaetoceros* resting spores and *Eucampia antarctica* during cold time intervals may reflect changes in productivity and/or decreases in salinity.

The occurrence pattern of sea-ice related taxa does not indicate influence of Antarctic sea ice during late Quaternary glacial time intervals at latitudes around and north of 46°30'S.

It may be speculated that these changes represent N-S shifts of the Sub-Antarctic front.

PRESENT STATUS OF THE RADIOCARBON CALIBRATION FOR THE LATE PLEISTOCENE

E. Bard (Univ. d'Aix-Marseille, France; Lamont-Doherty Geological Observatory, Palisades, NY, USA), M. Arnold, and B. Hamelin

We have measured the ages of coral specimens collected offshore of the atoll of Mururoa, French Polynesia. The samples were collected by means of a deviated drill (30°) at about 170 meters below present -day sea level.

Two geochronological techniques have been used: $^{230}Th/^{234}U$ by thermal ionization mass spectrometry (TIMS; LDGO) ^{14}C by accelerator mass spectrometry (AMS; Tandetron of Gif-sur-Yvette). The results show significant differences between the two geochronometers corresponding to $\Delta^{14}C$ values of 295 ± 25 ‰ and 340 ± 40 ‰ at about 16,000 and 18,000 Th-yr BP, respectively. This new comparative study of U-series and radiocarbon ages demonstrates that the large discrepancies first evidenced in Barbados (Bard et al., 1990) are not the results of local alteration processes, and that reef corals may be used successfully to calibrate the radiocarbon time scale.

A close comparison between these results and the German dendrochronological calibration (Becker et al., 1991; Kromer & Becker, 1992; in press) demonstrates that between 200 and 11,500 cal yr BP the U-Th ages are accurate (10 coral samples; agreement within 100 years with the dendrochronology).

Between 11,500 cal yr BP and 13,000 cal yr BP, the U-Th results are in agreement with estimates obtained from AMS dating of macrofossils found in the varved sediments of Lake Gosciaz, Poland (Rozanski et al., l992; Goslar et al., in press).

PRODUCTIVITY AND PLANKTIC FORAMINIFERAL CHANGES ACROSS THE CRETACEOUS - TERTIARY BOUNDARY IN HIGH LATITUDES

E. Barrera (Dept. of Geological and Geophysical Sciences, Princeton University, NJ, USA) and G. Keller

In the most complete published low and mid -latitude, deep-sea and shallow-water sections, the K/T boundary is marked by a pronounced decrease in $\delta^{13}C$ values of surface water carbonates and a reduction in the surface-to-bottom $\delta^{13}C$ gradient. This isotopic feature has often been interpreted to reflect a decline in productivity, responsible for the sudden extinction of many planktic foraminiferal species at or near the K/T boundary. We present foraminiferal faunal and isotopic data across two nearly complete K/T boundary transitions in the high latitudes, at ODP Site 738 in the Antarctic Indian Ocean and Nye Klov, in Denmark, each of which indicates that neither a decline in productivity nor a sudden mass extinction of planktic foraminiferal species occurred at the K/T boundary. Isotopic records are of monospecific samples.

The Site 738 K/T boundary, which is marked by a dark clay layer with high Ir (Schmitz et al., 1991), occurs ~2 cm above the base of a 15-cm thick clay-rich laminated interval. The portion of the laminated interval above the boundary contains the basal Paleocene foraminiferal zones P0 and P1a. The major faunal and environmental events, as evidenced by changes in abundance of the dominant planktic species, a reduction in the specimen size, increased sediment Ba content (Schmitz et al., 1991) and increased $\delta^{13}C$ values of bulk carbonate, coincided with the onset of laminated sedimentation, and continued in P0 and P1a. These proxies suggest increased surface water productivity during this time. Planktic foraminiferal $\delta^{13}C$ values are about constant across the K/T boundary at Nye Klov, suggesting no productivity decline in high northern latitudes. At Sites 738 and 690 (Stott and Kennett, 1989), $\delta^{13}C$ values of bulk carbonate samples, and planktic and benthic foraminifera decreased briefly in Zone P1b, ~230,000 yrs after the K/T boundary. As in the low latitudes, normal conditions evidenced by a normal surface-to-bottom $\delta^{13}C$ gradient and the evolution of more complex planktic species resumed ~0.3-0.5 m.y. after the K/T boundary event. These high latitude data suggest that the bolide impact had a greater environmental effect in the low latitudes than in the high latitudes and was not the cause of the K/T boundary faunal transition.

CENOZOIC CLIMATE AND OCEAN MODELING

E.J. Barron (Earth System Science Center, Pennsylvania State Univ., University Park, USA) and L.C. Sloan

The extensive data base available to describe the evolution of ocean climate throughoutthe Cenozoic illustrates a number of abrupt changes and major contrasts from the present day which are ideal case studies for examining global change and climate sensitivity. In particular, the Paleocene-Eocene transition suggests that the ocean-atmosphere system can reorganize, producing a substantially different role for the oceans. This reorganization contributes to major changes in continental climates, ocean silica deposition, aeolian contribution to the oceans, distribution of benthos, and sea-surface temperatures. Elements of the climate record present a significant enigma when compared with model simulations, and the nature of the record and models are the subject of intense discussion.

A time series of atmosphere and ocean general circulation model simulations for several time slices throughout the Cenozoic have illustrated the role of geography and polar ice cap growth in controlling the nature of the ocean circulation, including the developmentof the circum-Antarctic current, the Atlantic Ocean gyres, the equatorial circulation with the closure of Tethys, and the complex role of Indian Ocean geometries in ocean current evolution. However, the abrupt changes are not evident from the characteristics of the surface circulation. Additional analyses illustrate substantial changes in deep-water circulation which provide significant evidence for a re-organization of the ocean-atmosphere system and a significantly greater role of the Eocene ocean in transporting heat poleward. Further,the nature of the continental geometries and the nature of the circulation promote substantial differences in surface salinity which can be compared directly with the distribution of biota.

In combination, these studies provide a physically consistent interpretation of the re-organization at the Paleocene-Eocene boundary and suggest the importance of the role of the ocean in global change studies. These results also guide new simulations of the Cenozoic, utilizing a high-resolution ocean general circulation model.

INFLUENCE OF MONSOON ON PELAGIC CARBONATE SEDIMENTATION IN THE EQUATORIAL INDIAN OCEAN: HIGH-RESOLUTION RECORD FROM A 54 M PISTON CORE

F.C. Bassinot (CNRS-Luminy, Marseille, France), L. Labeyrie, E. Vincent, L. Beaufort, Y. Lancelot, L. Meynadier, and J.P. Valet

During the SEYMAMA cruise aboard RV *Marion Dufresne*, pelagic carbonates deposited with high sedimentation rates (>5 cm/kyr) were cored in the eastern shoulder of the Maldives ridge (northern equatorial Indian Ocean) with a giant piston coring system. The longest core, MD900963 (54 m in length, at a water depth of 2450 m), contains a detailed record of Pleistocene climatic and oceanographic variabilities.

The top 41 m cover the entire late Pleistocene down to oxygen isotopic stage 23.0. Discrete substages in the $\delta^{18}O$ curve are especially well-expressed owing to the superimposition on the global glacial signal of a local salinity effect controlled by changes in monsoon intensity. We developed a precise chronology by fine-tuning this detailed $\delta^{18}O$ record on astronomical forcing functions. The resulting chronology resembles closely the chronology developed at ODP Site 677 (eastern equatorial Pacific), with the Brunhes/Matuyama reversal dated at 780 kyr.

The carbonate curve closely mimics the $\delta^{18}O$ curve with higher carbonate contents, as well as higher accumulation rates, during interglacial stages. Despite the shallow location of the core, 1200 m above the present lysocline, carbonate dissolution controls changes in grain size, as evidenced by a clear inverse relationship between sand content and foraminifer fragmentation.

Dissolution, however, has only a subordinate effect on the carbonate content. Spectral density of dissolution cycles displays a clear maximum centered on the 23 kyr^{-1} frequency with little power at the 100 kyr^{-1} frequency, whereas carbonate content fluctuates with a dominant 100 kyr^{-1} frequency. Major changes in carbonate content are likely the result of changes in carbonate productivity. Dissolution pulses at the 23 kyr^{-1} frequency are probably controlled by the oxidation of organic matter incorporated into the sediments in greater quantities during cooler intervals. Lower frequency cycles (e.g., at 100 kyr^{-1}) probably result from global changes in deep-water chemistry because these cycles correlate quite well with fluctuations of the Common Dissolution Index (CDI) curve of Peterson and Prell (1985; core V34-53, Ninetyeast Ridge).

SONOSTRATIGRAPHY OF EQUATORIAL INDIAN OCEAN PISTON CORES: TOWARD A RAPID AND HIGH-RESOLUTION TOOL FOR TRACKING DISSOLUTION CYCLES IN PLEISTOCENE CARBONATE SEDIMENTS

F. C. Bassinot (CNRS-Luminy, Marseille, France), L. Beaufort, Y. Lancelot, and E. Vincent

Major fluctuations in the sand content of Pleistocene pelagic carbonate sediments deposited between 2000 and 3700 m of water depth have been correlated throughout the entire equatorial Indian Ocean from the Seychelles area eastward to the Ninetyeast Ridge, and into the Arabian Sea (using ODP sites 722 and 758, and four giant piston cores collected from RV *Marion Dufresne* during the SEYMAMA expedition). These changes in grain size result from changes in carbonate dissolution as evidenced by the clear inverse relationship between sand content and foraminifer fragmentation observed in two of the giant piston cores. A 500 kyr dissolution supercycle can be readily recognized in the grain-size curves. Higher frequency cycles appear to correlate fairly well with fluctuations of the Composite Dissolution Index (CDI) curve of core V34-53 (Ninetyeast Ridge; Peterson and Prell, 1985).

P-wave velocities were measured in the giant piston cores at a 5-10 cm interval. The velocity profiles closely match our grain-size curves as expected in pelagic carbonate sediments. Intercore correlations are thus possible based on velocity profiles, allowing development of sonostratigraphy for equatorial Indian Ocean pelagic sediments.

Measuring P-wave velocities in Pleistocene carbonate sediments gives quick and easy-to-obtain information on dissolution cycles in areas where the grain size is mainly controlled by dissolution pulses. In such cases, the continuous laboratory records obtained with P-wave loggers (1-2 cm sample interval) will provide near-continuous dissolution records.

PHOSPHORITES AS AN UPWELLING PRODUCT

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Most phosphorites have been formed in the marine environment, including ancient phosphorites now on land. Their geologic age span is from late Pre-Cambrian to Recent.

The common features of all phosphorites are their morphology (pelletal, nodular and micro-phosphoric varieties); composition of phosphate mineral; behavior of some associated macro- and microelements.

The environmental conditions of different phosphorite formations have also much in common. Nearly all phosphorites are of shallow water origin. Most of these are associated with biogenous rocks: silicious, calcareous and carbonaceous. It is recognized that biogenic factors played the decisive role in their formation.

According to paleontologic data, the major types of phosphorites coincide with biogenic oncolithic, girvanellous and stromatolithic formations and major phosphorite-producing periods are characterized by abundant organic life in ancient basins.

The major factor responsible for high biologic productivity in the ocean is the upwelling phenomenon which is immanent to various types of water circulation, especially in coastal environment. The Recent and Late Quaternary phosphorites on the Namibian and Peru-Chile shelves are undoubtly products of coastal upwelling, including phosphorous input, high biological productivity, bioassimmilation and biosedimentation of phosphorus and, with it, subsequent diagenetic redistribution in sediments and formation of phosphatic pellets and nodules. The final stage of the process consists of sediment reworking and secondary enrichment of phosphatic components. Analogous was the course of events during the formation of most Miocene and Cretaceous phosphorite deposits.

TEST SIZE VARIATIONS OF PLANKTIC FORAMINIFERS AS RESPONSE TO CLIMATIC CHANGES

H.A. Bauch (Special Research Project 313, Kiel, Germany)

For the first time biometric analyses on shells of *Globigerina quinqueloba* (Natland) are used for palaeoceanographic interpretations in the Norwegian-Greenland Sea (NGS). Several top box-cores have been investigated along a transect (Vøring Plateau-Kolbeinsey Ridge) with sediments covering the climatic changes since the Last Glacial Maximum (LGM).

G. quinqueloba proved to be extremely valuable because it is the most abundant of all subpolar planktic foraminifers in interglacial NGS and almost ubiquitous during Holocene times. Hence, it is bound to reflect oceanographic changes that occurred since first interglacial warming.
Methods were carried out by measuring the largest diameter of the test across the umbilical side from appropriate split-samples of the 63-500 µm size-fraction. Morphological variations are low due to an almost spherical circumference, low trochospiral shape and constant numbers of chambers in the final whorl.

Both median and mean-size variations exhibit an increase after LGM that cumulates during the Holocene climatic optimum (~6,000 B.P.) and decrease again in surface sediments. Essentially, sizes are much larger at the Vøring Plateau in the vicinity of incoming Atlantic water than in the west. But there are strong indications that *G. quinqueloba* first appeared in the south-western part of the NGS with a preliminary major peak in abundance and size well below the Younger Dryas. In fact, this species seems to have been present in sizes <125µm during entire oxygen isotopic stage 2. This cannot be observed in the more easterly investigated cores.

It seems likely that size variations, as a 'tool' for palaeo-oceanographic interpretations, are not only valuable for the time since LGM, but can also be applied for older isotopic stages where abundances of *G. quinqueloba* are low in >125 µm fraction, but appear to be high in the 63-125 µm fraction (e.g., stage 7,9, and 11).

LATE QUATERNARY DINOFLAGELLATE CYST ECOSTRATIGRAPHY IN THE NORTHEASTERN NORTH ATLANTIC AND NORWEGIAN SEA

A. Baumann (Special Research Project 313, Kiel, Germany)

Late glacial and Holocene dinoflagellate cyst assemblages have been studied in sediment cores located on a transect from Rockall Plateau to Fram Strait. Today this region is influenced by Atlantic surface waters which are transported by the North Atlantic drift and the Norwegian current into the Norwegian Sea.

Distinct temporal and spatial patterns in the distribution of assemblages are related to climatic oscillations in the oceanic environment since Termination I. In the late glacial interval discontinuous input of meltwater associated with warming events caused strong variations in the dinoflagellate cyst record.

The transition to the Holocene is marked by a distinct change in the composition of assemblages, as well as by an increase in absolute numbers. In early Holocene the dinoflagellate cyst record suggests that Arctic surface water masses extended into the western Norwegian Sea. The Arctic Front must have been located east of its modern position during summer indicating stronger hydrographical gradients in surface-water masses in the Norwegian Sea. The transition to modern conditions occurred in Mid-Holocene, and the Arctic Front retreated into the Greenland and Iceland Sea until around 6000 yrs. BP. A trend to cooler conditions is recorded in the surface sediments of some cores.

CLIMATIC CHANGE IN THE NORWEGIAN-GREENLAND SEA AND FRAM STRAIT DURING THE LAST 300,000 YEARS: ICE-RAFTED, TERRIGENOUS INPUT VERSUS CARBONATE FLUX

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Late Pleistocene climate changes are observed in 20 long sediment cores from the entire Norwegian-Greenland Sea (NGS) and Fram Strait by investigating variations in calcareous biogenic versus coarse terrigenous input.

Time control is based on high-resolution oxygen isotope stratigraphy. Detailed studies on the composition and distribution of terrigenous components in the coarse fraction (125-500μm) show important episodic fluctuations which reflect variations in ice-rafting.

Generally high amounts of lithogenic material in glacial sediments from the eastern and central NGS reflect enhanced deposition of coarse ice-rafted detritus (IRD), indicating that melting of ice occurred in this area. Carbonate content is highest in peak interglacials (e. g., oxygen isotope stages 1, 5.1, 5.5), indicating maximum intrusion of warm Atlantic surface waters.

In contrast, the northern Greenland Sea and Fram Strait sediments from peak interglacials, and also from intervals of maximum glaciation (e.g., stages 1, 2, 5.5, 5.1, 6.2) are characterized by relatively low amounts of coarse terrigenous material. Relatively high carbonate contents indicate only little dilution by fine-grained terrigenous material and a minimum of ice melting. However, during times of intermediate conditions, terrigenous input was strongly dominating and carbonate flux was extremely low, indicating extensive ice melting and IRD-deposition.

Regional and spatial variability of these parameters allows the reconstruction of changes in surface current systems, ice covers and biologic productivity in the Norwegian-Greenland Sea and Fram Strait in response to global climatic changes.

GEOCHEMICAL VARIATIONS IN MN-CRUSTS OF DIFFERENT WATER DEPTHS DURING THE LAST 300,000 YEARS: IMPLICATIONS TO THE WATER COLUMN?

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This study is concerned with ^{230}Th- and ^{10}Be-dating and determination of major and trace elements of the uppermost surface-millimeter of manganese encrustations of different water depths. Based on the prediction of growing by direct precipitation of the main elements from the water column, we want to study with these analysis geochemical variations of ocean water masses in different water depths.

Earlier studies (Eisenhauer et al., 1992) have pointed out by high resolution ^{230}Th-dating on a few samples that there are characteristic variations in the specific activity of ^{230}Th. Further investigated Mn-crusts of different water depths indicate a similar trend. Assuming a constant flux model, the calculated accumulation rates reveal higher growth rates during interglacial times and lower growth rates during glacials.

Using the "constant flux" model for ^{230}Th, these variations of accumulations rates can be interpreted as the result of dilution; Mn- and Fe-oxides are expected to act as the main dilution phases. Analysis of the major and trace elements confirm a positive correlation between higher Mn, Fe- and Co-flux into the investigated crusts and higher accumulation rates.

A positive element correlation between Co and Mn demonstrates that precipitation of Co from the water column is also associated with paleoclimate. This data confirm earlier suggestions that the main carrier phase for Co is δ-MnO_2, which is supposed to be the typical mineral phase growing during direct seawater precipitation.

With increasing water depth we found the following geochemical trends: (1) decreasing Mn/Fe ratios and decreasing Co-concentrations; this agrees with Halbach et al. (1983). (2) From the shallow water crust to the deep water crust we observed an increasing specific surface ^{230}Th-activity by a factor 2, which one can expect from ^{230}Th-production in the water column. (3) Sm increases with water depth by the same factor. This is in good agreement to increasing Sm-concentrations in the water column (Elderfield & Greaves, 1982). Other REE tend to have the same trend.

In the deep water crust (4800 m) remarkable variations of the Mn/Fe (up to 75%) could be observed. Our interpretation is that the development of these crusts was strongly influenced by depth variations of the CCD during paleoclimatic history. More intense dissolution of carbonates and associated released iron in the deep ocean result in variations of the Mn/Fe ratio.

MIDDLE MIOCENE CLIMATIC FLUCTUATIONS IN THE EASTERN EQUATORIAL PACIFIC OCEAN AT ODP SITE 845 (LEG 138)

L. Beaufort (CNRS-Luminy, Marseille, France) and E. Vincent

The termination of the "Mid Miocene Cooling Event" is not yet clearly understood. A 2.43 myr long sedimentary record with good biostratigraphic and magnetostrigraphic control obtained at ODP Site 845 (Leg 138) between chrons 5AB and 5 (13.56 to 11.03 Ma) was quantatively analyzed for calcareous nannofossil assemblages. Changes of the relative abundance of three taxa (*Sphenolithus neoabies*, *Discoaster* spp. and *Coccolithus pelagicus*) were identified with a time resolution of about 10 kyr. Sphenoliths are at one end of the spectrum of variation, whereas *C. pelagicus* is at its other end, and discoasters in the middle. It is mostly plausible that this spectrum of variation corresponds to a temperature gradient based on our knowledge of the paleoecology of the species. The variations in nannofossil assemblages match those in the sediment density continuously measured using a Gamma Ray Attenuation Porosity Evaluator, which in turn reflects changes in carbonate content. The arguments over why carbonate dissolution is not the controlling factor of the variations in the composition of the calcareous nannofossil assemblages are discussed.

Neither clear long-term tendencies, nor a step-like behavior were observed in these series. Rather, they fluctuate quite regularly. Spectrum analysis reveals that an important 100 kyr periodicity present in the oldest part of the record disappears at about 12.5 Ma near the end of the "Mid Miocene Cooling Event". The presence of an 100 kyr cycle prior to 12.5 Ma is probably linked with larger ice volume stored at high latitudes (as during the Pleistocene).

SEA-SURFACE TEMPERATURE FROM CORAL Sr/Ca RATIOS

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Mean monthly records of tropical sea surface temperature (SST) over the past 10^5 years can be recovered from high-precision measurements of coral Sr/Ca ratios with the use of thermal ionization mass spectrometry. This study calibrates the temperature dependance of Sr/Ca ratios for corals collected at two SST recording stations using $^{18}O/^{16}O$ thermometry and compares these derived Sr/Ca temperatures with actual records of SST. The results suggest that mean monthly SST may be determined with an apparent accuracy of better than 0.5°C. Measurements on a fossil coral indicate that 9900 radiocarbon years ago mean annual SST's near Vanuatu in the Southwest Pacific were about 5°C colder than today and that seasonal variations in SST were larger. This suggests that tropical climate zones may have been compressed towards the equator during deglaciation. These findings corroborate estimates of SST based on the elevation of past mountain snow lines, but are at variance with those suggested by CLIMAP reconstructions.

Measurement of coral Sr/Ca ratios in concert with coral $^{18}O/^{16}O$ measurements may make it possible to determine sea-surface $\delta^{18}O$ by removal of the temperature component of the coral $\delta^{18}O$ signal. Maps of sea-surface $\delta^{18}O$ generated in this way might be used to estimate variations in the volume of the planetary ice caps, or to generate maps of sea-surface salinity. The latter

might in principle be used to recover past patterns of rainfall and evaporation over the tropical oceans.

DEEP-SEA PALEOCIRCULATION AND PALEOENVIRONMENT OVER THE PAST 30,000 YEARS IN THE N.E. ATLANTIC OCEAN: THE BENTHIC MICROFAUNA RECORD

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The use of deep-sea benthic foraminifera and ostracoda as "tracers" of water masses and physico-chemical parameters is now well-developed.

During the last 10 years, the life occurrence of microfauna on and in the sediment has been studied, namely: microhabitat between the surface sediment and 15 cm depth, correlation between morphologies and oxygenation rate, impact of seasonality on downward organic flux, and variations in the vertical distribution of microfauna.

These results are applied to the study of core 8722 located 2161m depth in the Rockall Basin (55°28'7N;14°41'7W).

Estimations of the oxygenation values of the bottom water from 30,000 years to the present are given. Variations of the organic matter input are shown.

The influence of the atmospheric climatology is shown namely during the deglaciation and the lower Holocene.

HYDROGRAPHIC CHANGES BETWEEN THE EASTERN AND WESTERN MEDITERRANEAN BASIN DURING THE LAST DEGLACIATION

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We compared two sediment cores from the eastern Mediterranean Sea with one from the western Basin (Alboran Sea), with respect to micropaleontological, stable isotope and AMS radiocarbon data. This was done in order to reconstruct hydrographic changes in the surface waters during the last deglaciation. The increased runoff after full glacial conditions led to a density stratification of the water column and a circulation reversal, from anti-estuarine to estuarine. This helped to enhance the productivity in the upper water column and to decrease the oxygen content of the deeper water. Due to the increasing anoxic conditions of the bottom waters, a protosapropel and, eventually, a sapropel was formed. Our data indicate that the climate amelioration leading to the buildup of these adverse conditions was punctuated by an aridity event. This is reflected by an interruption of the gradual decrease in the surface water $\delta^{18}O$ record between 11,000 and 10,000 years BP in all three cores, coinciding with the Younger Dryas event. In the eastern Mediterranean this was directly followed by a rapid decrease of 6.0 per mil in $\delta^{13}C$. The core closest to the Nile River experienced this carbon shift, first suggesting that it was caused by a rather sudden reinforcement of continental runoff.

DISTRIBUTION OF ^{210}Po IN THE NORTH SEA

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The radiochemistry of the naturally occurring radionuclide isotope ^{210}Po was studied in the North Sea. The concentrations of ^{210}Po for both dissolved and particulate phases were determined at 36 stations. At each station samples were taken at two different depths: at the surface and 5 m above the seabed.

Aim of this work is to study the distribution and scavenging of ^{210}Po and ^{210}Pb in the water column and, furthermore, particle transport in the North Sea.

Further measurements consist of: salinity, density, particle size distribution, particle concentration, and organic matter content. Atmospheric input of ^{210}Po and ^{210}Pb is estimated from measurements on land.

ON BENTHIC FORAMINIFERAL PALEOENVIRONMENTS ACROSS THE K/T BOUNDARY, NEGEV, ISRAEL

Ch. Benjamini (Ben Gurion University, Beer Sheva, Israel), G. Keller, and L. Perelis-Grossovicz

Benthic foraminiferal populations from across the K/T boundary were studied quantitatively, to determine population changes and their paleoenvironmental implications. Three sections, at the Sinai border, at Ben Gurion in the central Negev, and at Zofar in the eastern Negev, were examined. Correlation was by means of planktic foraminifera.

Relatively few species actually became extinct at the K/T boundary, but dominance patterns of many species were affected by the event. The fauna can be divided into several groups, viz: species which dominated in the Cretaceous, species which characterize the transitional interval of the Lower Danian (Po-P1c), and species which became important only in the Tertiary (P1c, P1d).

The dominant Cretaceous species were primarily infaunal, mostly buliminids. They were rapidly replaced in the Tertiary by trochoform species, e.g. *Gavelinella beccariformis* and abundant Cibicidids. We deduce that the main, long-term environmental perturbation across this boundary was reduction of productivity, contraction of the O_2 minimum zone, and colonization of this area by an outer continental shelf fauna. A deepening trend is indicated by increased abundance of several characteristic species, e.g., *Angulogavelinella avnimelechi* and *Nuttalides truempyi.*

The transitional interval is characterized by rapid fluctuation in abundance of several species which originally appear as abundance spikes in the Cretaceous, e.g., *Tappanina selmensis,* and *Nuttalides florealis.* Late in the Danian, these increase with the deepening trend. This trend is evidence for an extended period of short-term environmental perturbations, beginning in the Cretaceous, continuing well into the Tertiary, and superimposed on the long-term trend of environmental change across this boundary in the Negev.

REACTIONS TO SOLAR PUMPING IN THE RIFIAN CORRIDOR LEADING TO THE MESSINIAN SALINITY CRISIS

R.H. Benson (Smithsonian Institution, Washington, DC, USA), D.A. Hodell, K. Rakic-El Bied, D.V. Kent, and L.-A.C. Hayek

New excavations and drilling in the upper Miocene part (6.4 to 5.4 Ma; Messinian) of the continuous Bou Regreg marl section near Rabat have yielded color banding, cyclic variations in carbonate, and oscillations in fauna believed to be linked to the Milankovich cycle. This record was deposited at the western entrance of the Rifian Corridor, the last major connection with the Atlantic of the Paleo-Mediterranean before its isolation during the Messinian salinity crisis. We propose a model of energy transfer driving the water-mass budget deficit of the Paleo-Mediterranean and climate changes in the northern Sahara, linked to variations in solar insolation at 35 degrees latitude.

NEOGENE DEEP-SEA CARBONATE SEDIMENTATION: SOME BASIC QUESTIONS

W.H. Berger (Scripps Institution of Oceanography, UCSD, La Jolla, CA, USA)

Carbonate sedimentation on the deep sea is traditionally understood as the result of a balance between carbonate supply and dissolution, with a balance between the two achieved at the carbonate compensation depth (CCD). Major changes in patterns are described, therefore, as changes in the level of the CCD in space and time. To this may be added changes in the depth gradient of accumulation rates, which have been interpreted in terms of changes in the rates of dissolution at depth. Another descriptor of the system has been fluctuations of the lysocline (and other levels of equal preservation) whose amplitudes are tied to changes in saturation and, hence, the atmospheric carbon dioxide content.

Recent results from a depth transect drilled on Ontong Java Plateau suggest that the current conceptualization of carbonate accumulation rates were found to vary greatly (factor of 3) even at shallow depths. Rates do decrease with depth, as expected, but this decrease is much greater than calculated from carbonate content, under the assumption that dissolution is the cause of the decrease. This points to a complex of factors responsible for large-scale redeposition processes intimately tied to dissolution.

EVALUATION OF POROSITY AND WET BULK DENSITY OF ARCTIC SEDIMENTS BY HIGH-RESOLUTION MEASUREMENTS OF ELECTRICAL RESISTIVITY

U. Bergmann (Universität Bremen, Germany) and H. Kassens

During the cruise ARCTIC' 91 with RV POLARSTERN into the central Arctic Ocean, sediment physical properties were routinely measured on piston and square-barrel Kastenlot cores. Index parameters, including water content and bulk density, were determined by direct measurements of total mass, dry mass, and total volume of the samples. Other parameters (e.g., porosity) can be derived from these two basic properties.

In addition to this laborious and time consuming standard method, high-resolution measurements of electrical resistivity were tested for a rapid (20 minutes per meter) and efficient logging of porosity and wet bulk density on basis of empirical relationships:

The ratio of electrical resistivity of water-saturated sediment to electrical resistivity of interstitial water at a given temperature, pressure, and salinity is related to porosity by the Archie formula. Wet bulk density was determined from these porosity data assuming a constant grain density and a constant interstitial water density.

For the electrical resistivity measurements, a miniaturized Wenner configuration was used. The Wenner probe consists of a narrow plastic strip (16 x 4 x 100 mm) with four platinum wires.

Wet bulk density and porosity logs derived from electrical resistivity measurements were found to be in excellent agreement (differences < ±0.5%) with wet bulk density and porosity data determined by standard methods.

MODERN BENTHIC FORAMINIFERA IN SURFACE SEDIMENTS OF THE CENTRAL ARCTIC OCEAN

H. Bergsten (Dept. of Oceanography, Univ. of Göteborg, Sweden)

The "ARCTIC 91" cruise with the two vessels ODEN (Sweden) and POLARSTERN (Germany) to the central Arctic Ocean has provided the possibility to study the modern distribution of benthic foraminifera from this area. The central parts of the Arctic Ocean have, until now, been very poorly investigated.

Modern benthic foraminifera from this area show some different types of Arctic benthic environments. Surface samples in a transect from the North Pole to the Yermak Plateau contain abundant benthic, as well as planktic foraminifera. The samples cover a water depth range between 552 m and 4411 m and represent some sites which are seasonally ice-free, even though most sites are characterized by permanent sea-ice.

Foraminiferal assemblages are predominantly calcareous both in total number of specimens and species, and the planktonic/benthic (P/B) ratio generally increases towards the north. The total number of benthic foraminifera varies between 30 and 2,340 per cc sediment and the P/B ratio varies between 0.3 and 32. The frequencies of stained ("living") species are relatively high (15-25%) on the southern Yermak Plateau, while they are <3% in the Nansen and Amundsen Basins, and the Morris Jesup Rise.

On the southern Yermak Plateau the benthic foraminiferal communities resemble those of northern shelf areas, while the northern Yermak Plateau, the Nansen and Amundsen Basins, and the Morris Jesup Rise display different assemblages. *Stetsonia arctica* generally dominates at depths >2,500 m. Additional common species are, e.g., *Triloculina tricarinata, Eponides tumidus* and *Oridorsalis umbonatus* . *Glabratella arctica*, which is previously reported from single stations in the Arctic Ocean, has been found at some sites occurring with high frequencies.

There is no evidence from the Modern foraminiferal faunas that the bottom waters are undersaturated with respect to calcium carbonate. Not even assemblages from the deepest areas in the Arctic Ocean seem to undergo dissolution, and all areas appear, therefore, to lie above the CCD.

CONTROLS ON THE CARBON ISOTOPE COMPOSITION OF SEDIMENTARY ORGANIC MATTER AND CARBON CYCLING IN A PERMANENTLY ANOXIC BASIN: AN ACTUALISTIC LACUSTRINE MODEL

S. Bernasconi (Geologisches Institut, ETH-Zentrum, Zürich, Switzerland), R. Peduzzi, and J.A. McKenzie

Organic-carbon isotope geochemistry is increasingly being used as a tool for paleoproductivity and paleoclimatic reconstructions in both marine and lacustrine environments. Because of their small size, lakes are more easily studied than marine environments and can be used as small-scale models to improve our understanding of oceanographic processes. Lake Cadagno in Southern Switzerland provides a model environment to study the carbon cycling in permanently anoxic environments and to assess the impact of autotrophic and heterotrophic bacterial activity in the water column on the carbon isotope composition of sedimentary organic matter.

Lake Cadagno is a 21 m deep Alpine meromictic lake characterized by permanently anoxic waters below 12-14 m water depth. At the oxic-anoxic interface a bacterial plate composed of phototrophic purple sulfur bacteria and heterotrophic bacteria is present year round. The phototrophic bacteria at the chemocline are responsible for an additional primary productivity which represent approximately 25% of the total lake productivity. Preliminary data show that the bacterial plate acts as a barrier that prevents recycling by diffusion of remineralized CO_2 and nutrients into the photic zone. Stable carbon isotope and elemental composition of phytoplankton, bacterioplankton and particulate organic matter are used to model the carbon cycling in the water column. Changes in organic matter composition during settling in the water column and early diagenesis are evaluated to quantify the relative importance of the different sources of organic matter in the sediments.

CADMIUM/CALCIUM AND CARBON ISOTOPE RECONSTRUCTIONS OF THE GLACIAL NORTH-EAST ATLANTIC WATER COLUMN

C. Bertram (Godwin Lab, Univ. of Cambridge, UK), N.J. Shackleton, J. MacDonald, and H. Elderfield

The concentration of cadmium in foraminifera may be used as a geochemical tracer of oceanic phosphate distributions. Nutrient distribution patterns are controlled by ocean circulation and interaction with the oceanic biogeochemical cycle; thus, temporal variations in nutrient distributions reflect changes in ocean circulation and chemistry.

Cd/Ca and $\delta^{13}C$ measurements have been made in benthonic foraminifera (mainly *C. wuellerstorfi*) extracted from BOFS (Biogeochemical Ocean Flux Study) North Atlantic sediment cores: 14K (1756m) and 17K (1150m) from present-day Intermediate Water depths, and 5K from deeper water (3547m).

All three cores have well-established stratigraphies based on planktonic $\delta^{18}O$ records, faunal records and magnetic susceptibility (Maslin et. al. poster). In both the intermediate water cores, $\delta^{13}C$ values at the last glacial maximum are significantly more positive than core-top values, whereas core 5K, in deeper water, displays the well-known light $\delta^{13}C$ values at the glacial maximum.

Measurements of Cd/Ca ratios in benthonic foraminifera are consistent with those of Boyle and Keigwin (1986, 1987) for the western North Atlantic an confirm the inference from the $\delta^{13}C$ data, that while the deep waters of the glacial North Atlantic were enriched in nutrients compared to the present day, there was an intense production of very cold, low-nutrient intermediate waters.

SEA-LEVEL AND CLIMATE CONTROL ON THE EVOLUTION OF AN ISOLATED CARBONATE PLATFORM: THE QUEENSLAND PLATEAU, NE AUSTRALIA (ODP LEG 133)

Ch. Betzler (Geologisch-Paläontologisches Institut, Frankfurt, Germany) and T. Brachert

The Queensland Plateau carbonate platform is characterized by a complex evolutionary history which is punctuated by several interruptions of platform growth. Three stages of platform development are distinguished. Sea-level fluctuations had a major control on depositional hiatuses, whereas surface water temperatures influenced neritic faunal assemblages.

The surface of the plateau (metamorphic rocks) was flooded during an early to Middle Eocene marine transgression. A carbonate platform was established, dominated by bryozoan-rich temperate to cool-water deposits. Periods of warmer water conditions may be indicated by intervals rich in larger benthic foraminifers. During the latest Middle Eocene, a drop in sea-level prevented continued platform growth (Upper Eocene-Lower Oligocene regional unconformity).

The second, Upper Oligocene to Middle Miocene carbonate platform stage, is characterized by tropical to subtropical faunal assemblages. Exposure surfaces within this interval document several minor drops in sea-level. At the Middle/Upper Miocene boundary a more pronounced lowering of the sea-level produced widespread exposure of the buildup.

During the Late Miocene (third stage), partial drowning of the platform occurred as a consequence of a combination of rising sea-level and accentuated subsidence rate of the basement.

UPWELLING SIGNALS OFF NORTH WEST AFRICA DURING THE LAST 30KA

N.A.S. Beveridge (Dept. of Earth Sciences, Univ. of Cambridge, UK) and H. Elderfield

Data from Kasten cores taken from the distal upwelling zone off N.W. Africa provide a useful insight into the relationship between meridonal wind strength, upwelling and low-latitude productivity over the last 30ka.

Upwelling off N.W. Africa is driven by the interaction of the Canary current and the prevailing trade winds, which blow parallel to the coast. Non-carbonate grain-size data and trace metal data indicate a more vigorous atmospheric circulation in terms of the major zonal dust-bearing Harmattan wind and the trade winds which induce coastal upwelling during the glacial period.

Temperature records based on faunal assemblages (Mix, 1986) and planktic oxygen isotope data over the upwelling zone confirm the idea of enhanced upwelling during the glacial period.

Productivity is intimately associated with upwelling. Enhanced productivity during glacial periods at critical low-latitude upwelling sites is seen as an important mechanism in reducing atmospheric pCO_2. High glacial opal rain rates and Ba/Al ratios seem to confirm the model of increased glacial upwelling.

However, the organic carbon flux, which is one of the most reliable indicators of palaeoproductivity shows little variation between glacial and Holocene times. Further evidence is needed to reconcile this contradictory data.

TIME SERIES STUDIES OF OCEAN PROPERTIES IN THE NORWEGIAN-ICELAND SEA OVER THE PAST 400,000 YEARS

I. Beyer (Dept. of Geology, Univ. of Bergen, Norway) and E. Jansen

The Norwegian-Iceland Sea exerts an important influence on the global climate system through transfer of sensible and latent heat to the atmosphere, deep-water formation and global deep-ocean ventilation. Time series of three stable isotope records, covering the last 400,000 years, provide new knowledge about the climatic responses in this sensitive area. Light oxygen isotopic peaks interpreted as glacial meltwater pulses reflect a strong 100,000 and 23,000 years cyclicity and indicate a strong precessional influence on the dynamics of the northern hemisphere ice-sheets. In spite of these low salinity pulses, deep water ventilation (observed by $\delta^{13}C$-records) seems not to be affected by reduced salinity except during major deglaciations. Frequency spectra of $\delta^{13}C$-records reveal strong 100,000 and 41,000 years cyclicity and indicate a close relationship between deep-water ventilation and obliquity.

Cross-spectral analyses of the isotopic signals vs. insolation (65°N) seems further to state the importance of orbital influence on the ocean circulation. Phase diagrams provide reasons to propose that the Norwegian-Iceland Sea remained ventilated during the first phase of glacial ice growth.

RECONSTRUCTION OF LATE QUATERNARY, BOTTOM-WATER CIRCULATION IN THE EASTERN SOUTH ATLANTIC: STABLE ISOTOPES IN BENTHIC FORAMINIFERA

T. Bickert (Universität Bremen, Germany) and G. Wefer

$\delta^{13}C$ records of the epibenthic foraminifera, *C. wuellerstorfi*, from 11 gravity cores were used to reconstruct the history of bottom water circulation in the deep South Atlantic for the last 360,000 years. The cores are located in the four main basins (Brasil, Guinea, Angola, and Cape Basins) in water depths between 3000m and 4600m.

As a result of the reduction of NADW during the last glacial maximum, the Southern Component Water was higher in the water column and extended farther north than it does today. In reconstructing this water mass we can divide it into an upper part (USCW) with $\delta^{13}C$ values between 0.2 and 0.7‰ and a lower part (LSCW) marked by values of -0.2 to 0.2‰. The boundary lay in 3700m water depth near the equator and rose toward the southern ocean. The asymmetry observed in bottom-water circulation today (AABW/LCDW in western basins, NADW in eastern basins below 4000m) was not present. From comparison to a deep western Pacific core (ODP 806B, Bickert et al., 1992) there is evidence that the nutrient-enriched but oxygen-depleted LSCW resembles the glacial Pacific deep water. This is also true for the older $\delta^{18}O$, stages 4, 6, 8, and 10.

In some warmer periods of the glacial substages 3, 8.1, and 8.5, a drop in the LSCW/USCW boundary to a little below 4000m results again in a deep South Atlantic circulation asymmetry with USCW filling the deep Guinea and Angola

Basin, leaving them a bit more oxygenated than the deep western basins bathed in LSCW.

ABSOLUTE SEASONAL PALEOTEMPERATURES IN THE EASTERN AND WESTERN EQUATORIAL ATLANTIC: OXYGEN ISOTOPE RESULTS

K. Billups (Dept. of Geology, Univ. of California, Davis, USA) and H.J. Spero

Attempts to reconstruct absolute seasonal sea-surface temperatures from the fossil record using planktonic foraminiferal isotope data have been limited. This is due to: 1) the general use of multiple shell samples in isotopic studies, 2) difficulties in interpreting the intraspecific variability contained in fossil foraminiferal assemblages when individual shells are analyzed, and 3) imprecise estimates of the isotopic composition of sea water ($\delta^{18}O_w$) at a given interval in a core.

We use the stable isotopic composition of individual *Orbulina universa* to estimate absolute seasonal temperatures, temperature ranges and $\delta^{18}O_w$ for the oceanic mixed layer at a western an eastern equatorial Atlantic site during the climatic optimum and late glacial period (18 ka). Models based on isotope experiments with live *O. universa* are used to constrain depth habitats. The $\delta^{18}O_w$ shift between two core intervals is estimated by measuring the $\delta^{18}O$ difference between cumulative distribution curves of the individual foraminiferal isotope data from each interval.

Approximately 50 *O. universa* shells were analyzed from each interval. Glacial temperatures were calculated using $\Delta\delta^{18}O_w = 1.6$ ‰ Absolute seasonal temperatures for the mixed layer (Tmax, Tmin), as well as the corresponding seasonal temperature ranges (Δ T) were estimated from the extreme values of the *O. universa* $\delta^{18}O$ range. Results are summarized as follows. The intraspecific $\delta^{18}O$ range for the western equatorial Atlantic is 1.3 ‰ or Δ T = 6°C (Tmax = 31°C, Tmin = 25°C) during both the climatic optimum and at 18 ka. In the eastern equatorial Atlantic, the interspecific variability is 2.1 ‰ or Δ T = 10°C (Tmax = 29°C, Tmin = 19°C), and 1.7 ‰ (ΔT = 8°C, Tmax = 29°C, Tmin = 21°C) for the climatic optimum and at 18 ka respectively.

These results suggest that: 1) there is no measurable change in mixed-layer temperatures between these two time periods in the western equatorial Atlantic, and 2) the intensity of upwelling in the eastern equatorial Atlantic may have been more seasonal during the climatic optimum than at 18 ka. Our results are consistent with other studies of seasonality in the equatorial Atlantic using faunal transfer functions.

PRELIMINARY RESULTS OF A STUDY OF THE SEISMIC STRATIGRAPHY OF THE EASTERN EQUATORIAL PACIFIC

S.F. Bloomer (Dept. of Surveying Engineering, Univ. of New Brunswick, Fredericton, Canada), L.A. Mayer, and the Leg 138 Shipboard Scientific Party

The collection of Leg 138 well-log and shipboard physical property data, in conjunction with high-resolution seismic profiles, provides an opportunity to understand the paleoceanographic significance of seismic reflectors and to gain insight into the paleoceanographic evolution of the eastern equatorial Pacific.

Synthetic seismograms were generated at Sites 844-853 and were compared to the field records to determine the origin of seismic reflectors at each site. In general, the match between the synthetic and field records was good and allowed the origin, in terms of physical property variations, and the age of selected reflectors to be determined. These reflectors are usually associated with sharp variations in density which, in turn, are related to variations in carbonate content.

Between Sites 846 and 847, 5 reflector horizons were traced. The thickness of the sedimentary section from the top reflector (4 Ma) to the bottom reflector (6.5-7 Ma) is reasonably constant in general. However, the section above the top reflector generally thickens to the east and is greatly expanded at Site 846, and this may be related to the position of the Peru Current over the last 4 million years.

Five reflector packets were traced between Sites 850 and 851. The section between reflectors with ages of approximately 3.5-9 Ma abruptly thins (0.25 to 0.20 ms) north of 1°40'-1°50'N, with a corresponding change in the character of the top reflector packet (3.5-4.5 Ma). This correponds to an extreme density low and the presence of *T. longissima* in Site 850 cores, suggesting this marks the northern limit of high equatorial productivity at that time.

With further analysis between these and other sites, we hope to define both the spatial and temporal extent of major oceanographic "events" and to distinguish regional events from local ones.

A NEW INTERPRETATION OF FORAMINIFERAL AND OXYGEN ISOTOPE DATA

N. Blyum (Moscow State University, Russia), S. Kolokolov, and N. Oskina

Joint interpretation of the paleotemperature (T) data and results of $\delta^{18}O$ analysis of surface and deep-water planktic foraminifera species allows determination of isotopic composition ($\delta^{18}O_w$), paleodensity (D) and paleosalinity (S) of surface waters. Central regions of subtropical gyres of the Atlantic, Pacific and Indian Oceans were chosen.

"Isotopic" depth of *G. menardii* (mn) is connected with certain T (Shackleton, Vincent, 1978) and those of *G. trunatulinoides* (tr) and *G. inflata* (in) - with constant D (Curry, Matthews; 1981). During glaciation depth habitus of these species decreased together with T decrease and D increase. *G. ruber* (rb) living close to the surface changed.

$\Delta\delta^{18}O_{mn}$ between stages 1/2 comprises 1-1.2 ‰ which to the same value of $\Delta\delta^{18}O_w$ change in case T for the mn was constant. $\Delta\delta^{18}O_{sc}$ was by 0.7-0.8 ‰ larger because of T influence and of local water correction (ΔE-ΔP). $\Delta\delta^{18}O_{tr}$ is 0.5-0.7 ‰ showing the tr movement upwards for corresponding D in layers which higher T. Difference $\Delta\delta^{18}O_{sc}$ and $\Delta\delta^{18}O_{tr}$ indicates changes. $\delta^{18}O$ of the carbonates (c) and D are connected with T and s by the same quantitative relationships. With T change by 1° C in the 10-25° C diapason. $\delta^{18}O_c$ changes by 0.24‰, (Epstein et al., 1953) but D- by 0.24 δt and 1 ‰S - 0.76 δ_t (Cox et al., 1970). $\Delta\delta^{18}O_{sc(rb)\text{-}te(in)}$ in the tropical halystazes was 1.3-1.5‰ (1.3-1.5 δ_t).

According to the foraminiferal data (Barash-Blyum method), T in these regions decreased during stage 2 by 1.5-2° C ($\approx 0.4\delta_t$). The left 0.9 δ_t corresponds to S increase, which was about 1.2‰. This S value conforms to average oceanic S variations in the Late Pleistocene with ice volume growth by 45 10^6 km^3 (Broecker, 1982).

THE TROPIC RESOURCE CONTINUUM MODEL AND PALEOGENE PLANKTONIC FORAMINIFERA

A. Boersma (Microclimates Research Consultants, Stony Point, NY, USA), I. Premoli-Silva, and P. Hallok

Nutrients, including fixed nitrogen, phosphorus, and trace elements are essential for the production of organic matter by photosynthesis. Nutrient flux serves as one mechanism by which astronomic, geologic, meteorologic, and oceanographic processes influence the biosphere. The Trophic Resource Continuum Model, deduced from studies of modern plankton communities and foraminifera, makes the following predictions concerning Paleogene age planktonic foraminifera:

1. Moderately eutrophic times or well-mixed surface waters should produce relatively low diversity, high dominance foraminiferal faunas in the euphotic zone; extreme eutrophy could produce oligotaxic assemblages from which foraminifera are largely excluded; faunas would be composed of generalist and opportunistic species demonstrating high ecophenotypic variability; these would be times of heightened meridional thermal contrasts and invigorated ocean circulation, or could be caused by an episode of rapid mixing through the euphotic zone. This scenario is illustrated by the earliest Paleocene and Early Oligocene.

2. More oligotrophic conditions or times would be characterized by higher diversities among epipelagic and tropical foraminifera, lower specific dominance, and increased numbers of specialists; meridional thermal contrasts would be lower and the region of warm surface waters would expand; the thermocline and the chlorophyll maximum may deepen at lower latitudes; nutrients may be concentrated at the base of the thermocline; this is illustrated by the Early Eocene.

3. Evolution from relatively eutrophic to relatively oligotrophic conditions after an ocean mixing event would result in the gradual development of new euphotic niches while the warm zone of the mixed layer expands, and diversification of specialized epipelagic foraminifera; under unusually warm conditions, decreased production or warm upwelling may result in lower abundances of fertility-related species; cool water groups may evolve or simply change their geography; this is illustrated by the latest Paleocene and the Late Oligocene.

4. Evolution from relatively oligotrophic to relatively eutrophic conditions with the beginning of ocean mixing should result in the elimination of niches in the euphotic zone and decreased diversities of warm water groups; mesopelagic groups may evolve due to the changed thermal structure of their habitat and decreased nutrient availability, as nutrients are more efficiently circulated through the thermocline; this is illustrated by the Middle Eocene.

LATE QUATERNARY ARCTIC SEDIMENTS AS INDICATORS FOR DIFFERENT ICE COVERAGE

H. Bohrmann (GEOMAR, Kiel, Germany), R. Botz, P. Stoffers, and J. Thiede

Sediment cores from across the Gakkel Ridge (Arctic Ocean) were analyzed by means of radioisotopic age determination and various sedimentological parameters. The sediments consist of siliciclastic material. Due to the high topographic position on the Gakkel Ridge the sediments are of pelagic and ice-rafted origin. All studied sediment cores are quite similar in age,

sediment sequences and other related parameters and thus can easily be correlated across the ridge. Changes in sedimentation rates and sediment material 129 ky ago are clearly related to a rapid climatic change. Recent sediments deposited at the Gakkel Ridge consist of fine-grained ice-rafted material. The recent ice cover in the studied area consists of sea ice which transports such fine-grained material. There is evidence that sea-ice coverage was dominant during the last 129 ky because low sedimentation rates and sediment material were nearly the same during that period. During the ice age which lasted from 186 to 129 ky, coarse-grained material, which was deposited under high-sedimentation rates, suggest dominance of icebergs. The icebergs came from glaciated areas of the Siberian shelves. Various ice-rafted sediments suggest different origin on the shelves. Sedimentation rates from these sediments are highly variable but in parts with more than 10 cm/ky an order of magnitude higher than sedimentation rates determined on sediments which were deposited during the last 129ky. It can be suggested that ice-sheets of the eastern Siberian shelves, in general, did not reach the water line in glacial intervals during the last 129ky.

ANNUAL FLUX OF RADIOLARIA AND OTHER SHELLED PLANKTERS IN THE EASTERN EQUATORIAL ATLANTIC AT 853 m: SEASONAL VARIATIONS AND POLYCYSTINE SPECIES-SPECIFIC RESPONSES

D. Boltovskoy (Universidad de Buenos Aires, and CONICET, Argentina), V.A. Alder, and A. Abelmann

Shelled microplankters were counted, and polycystine species identified, in 20 time-series sediment trap samples from the eastern equatorial Atlantic (01°47.5'N, 11°07.6'W) at 853 m, between 3/1/89 and 3/16/90. Mean annual flux rates (ind./m/day) were: polycystines: 28,446, tintinnids: 27,275, foraminifers: 17,816, tintinnid cysts: 14,632, phaeodarians: 1370, and molluscs: 1192. These yields are noticeably higher than most previous data from various areas of the world ocean. Only 3% of the polycystines and 30% of the phaeodarians were represented by cells with protoplasm. We anticipate that foraminifer and radiolarian fluxes reflect fairly well their abundances in the plankton, but only 0.1% of the tintinnid loricae reach 900 m intact. With the exception of tintinnid cysts and molluscs, abundances were clearly coupled with total particle flux. It is suggested that tintinnid high reproduction rates are responsible for tightest associations between the output of their loricae and total flux. Fluxes of Foraminifera and Radiolaria, which have longer life spans, are more loosely coupled with total flux, and often show peaks approx. 20-40 days after those of the latter. Molluscs, with life spans of ca. 1 year, do not correlate with total flux. Juvenile *Nassellaria* comprised up to 44% of all polycystine shells (mean: 25%). In total, 187 polycystine taxa were recorded, yet only 6 accounted for >50% of all the individuals identified. Although some species did vary in relative abundance in association with total and polycystine flux rates, changes in assemblage composition were of very minor importance. Radiolarian equitability and the percentages of *Spumellaria* were significantly higher at times of lower polycystine flux, yet the fluctuations involved were also minor.

RADIOLARIAN SEDIMENTARY IMPRINT IN ATLANTIC EQUATORIAL SEDIMENTS: COMPARISON WITH THE YEARLY FLUX AT 853 m

D. Boltovskoy (Universidad de Buenos Aires, and CONICET, Argentina), V.A. Alder, and A. Abelmann

Radiolarian specific makeups in a series of 20 sediment trap samples covering an entire year (3/1/1989 to 3/16/1990, collected at 853 m) were compared with bottom (0-1 cm) materials from the same site (eastern equatorial Atlantic: 01°47.5'N, 11°07.6'W). Data on mean sediment accumulation rates at the site of the mooring (1.59 g/cm^2/ky), mean radiolarian flux at 883 m (28,446 shells/m^2/day), and abundance in the 0-1 cm bottom layer (48,258 shells/g) suggest that approx. 95% of the radiolarians produced are lost to the fossil record. The average correlation (relative abundances of 40 radiolarian species present at levels ≥1% in at least one sample) between the 20 flux samples and the sedimentary sample (r=0.878) was not significantly different from the average correlation between flux samples (r=0.886). Sediment-flux similarities were unassociated with the time of the year and with periods of enhanced radiolarian output. Two taxa had lower, and nine taxa had higher percentage contributions in the sediments than in any one sediment trap sample, and a few of the abundant species had averages up to 7 times higher in either the water column or the sediments. These dissimilar percentage loadings are attributed to selective dissolution, lateral subsurface and deep advection of shells from higher-latitude areas, and identification biases. As opposed to species-level inventories, family-level databases (including shells identified to family only) differed significantly between the water column and the sediments. *Spumellaria* (especially *Spongodiscidae*) were more abundant in the sediments (35%) than in the water-column (19%), while *Nassellaria* showed the opposite trend (64% and 80%, respectively). It is suggested that ease of identification of spongodiscid fragments and fragility of juvenile *nassellarians* are responsible for these differences.

WHAT ARE HEINRICH LAYERS TRYING TO TELL US?

G. Bond (Lamont-Doherty Geological Observatory, Palisades, NY, USA) and W.S. Broecker

It has now been reasonably well established (Bond et al., in press) that four of the six Heinrich layers in northern Atlantic sediment are the product of debris released from armadas of ice bergs launched from eastern Canada about 50,000, 40,000, 21,000, and 14,000 years ago. However, the cause of these events remains undetermined. So also does their relationship to ocean circulation. Intriguing is the observation that the last of these events falls right on Termination Ia. A coincidence? Or did a surge of the Laurentian ice sheet kill the ice age? Or did the death of the ice age trigger a massive collapse of the ice sheet? We promise no firm answer, but will explore this puzzle.

EVIDENCE FOR MASSIVE DISCHARGES OF ICEBERGS INTO THE GLACIAL NORTH ATLANTIC

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As first recognized by Heinrich (1988), a series of horizons rich in ice-rafted debris and unusually poor in foraminifera are present in northern Atlantic sediments of the last glacial period. Subsequent studies reveal that these deposits form a belt extending across the entire Atlantic. Within four of these units are layers with unusual properties. Each contains abundant detrital carbonate, higher amounts of amphibols and has clay-sized material with high K/Ar ages. ^{14}C ages of the two uppermost layers scatter around 14.5 ka (H1) and 20 ka (H2). The internal structure of all horizons and flux estimations give rise of a rapid deposition. The evidence leads us to propose that each layer records a massive discharge of icebergs originating in Canada. The deluges appear to be the product of sudden advances of ice streams onto continental shelves which may have been a consequence of dramatic cold events or stochastic surgings of the Canadian ice sheets. Reductions in $\delta^{18}O$ of planktonic foraminifera of up to 1 ‰ point to the existence of fresh-water lids in the North Atlantic region during these events.

CIRCULATION CHANGES ON CENTURY AND MILLENNIAL TIME SCALES IN THE NORTHERN ATLANTIC

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New results we have obtained from deep sea cores suggest that the North Atlantic's surface circulation has undergone a series of changes on century and millennial time scales during the last glaciation, during the Holocene and during the last interglacial period. The century scale variability is closely associated with millennial scale climate cycles, occurring as abrupt transitions at asymmetrical cycle boundaries and as sharp events superimposed on those cycles.

Within the Holocene are three abrupt coolings of surface water. Based on AMS-^{14}C ages, these may correlate with century scale cooling events identified in land records in North America and Europe, dated at 8500 years, at about 5800 years and at about 1400 years. During the glacial period millennial-scale cycles dominate the marine record and appear to correlate with the Dansgaard-Oeschger $\delta^{18}O$ cycles in Greenland ice cores. The marine cycles exhibit a gradual cooling followed by a sudden warming, exactly the asymmetry observed in the ice cores. Even needle-like oscillations that punctuate the gradual cooling in ice core cycles also appear in the marine record. AMS-^{14}C ages suggest that the abrupt warming and the sharp oscillations occurred within centuries at the most, comparable to the rates inferred for the similar events in the ice cores. In stage 5 and at the stage 4/5 boundary, we have also found asymmetric marine cycles on millennial time scales; here though, the asymmetry seems to record abrupt shifts from warm to cold, probably within centuries, followed by a gradual warming. This is the opposite of the direction of the abrupt temperature shifts during glaciation and during the transition to the Holocene.

Taken together, the data suggest that rapid, century and millennial scale changes in circulation are a pervasive feature of the North Atlantic's past

climate, occurring not only during glaciations but during the Holocene and during transitions between glacial and interglacial periods, as well. The directions of the abrupt changes apparently are not constant but, instead, reverse at transitions into glacial periods. The rapidity of these events, their forms and their persistence through glacial and non-glacial periods raise new questions about the mechanisms that drive abrupt climate change.

LATE NEOGENE BENTHIC FORAMINIFER MORPHOTYPES AS INDICATORS OF THE CLOSURE OF THE ISTHMUS OF PANAMA

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We have analyzed benthic foraminifer morphotypes from late Neogene sequences (5.5-1.7 Ma) in DSDP Hole 502A from the Colombia Basin (Caribbean Sea) and Hole 503 from the Guatemala Basin (Pacific Ocean) to determine whether the development of the Isthmus of Panama and resulting changes in bottom-water circulation affected the benthic fauna at any time during this period. Previous studies have suggested that the final closure of the Isthmus of Panama, which blocked the surface-water exchange between the tropical parts of the Atlantic and Pacific Oceans, occurred between 3.2 and 2.9 Ma. Two epifaunal morphotypes (biconvex and plano-convex) dominated the benthic foraminifer fauna in Hole 502A. We interpret fluctuating abundances of these morphotypes to reflect changes in the relative contribution of Circumpolar Deep Water (CPDW) and North Atlantic Deep Water (NADW) in the Colombia Basin. Great abundances of the epifaunal plano-convex morphotype (dominated by *Cibicidoides wuellerstorfi*) may reflect greater inflow of NADW into the Caribbean Sea, whereas great abundances of the epifaunal biconvex morphotype (dominated by *Nuttallides umbonifera*) suggest greater inflow of CPDW. We suggest that fluctuations in abundances of the epifaunal and infaunal morphotypes in Hole 503 record changes in the contribution of Antarctic Bottom Water (AABW) and primary productivity. The biconvex and plano-convex morphotypes dominated the fauna also in this hole. Comparison of the benthic epifaunal and infaunal morphotypes between Holes 502A and 503 suggests that the isolation of the Atlantic low-latitude bottom waters across the Isthmus of Panama was terminated before 5.0 Ma. For example, the plano-convex morphotype exhibits an increasing trend between 4.8 and 3.6 Ma in Hole 502A, whereas it decreased during the same interval in Hole 503. The same tendency can also be seen in the biconvex morphotype, which increased in relative abundance between 4.8 and 3.6 Ma in Hole 503, whereas it decreased in Hole 502A.

THE OXYGEN-18 CONTENT OF RECENT BIOGENIC SILICA (NATURAL DIATOM ASSOCIATIONS AND CULTURES) AND POSSIBLE IMPLICATIONS ON DIATOM ISOTOPE STRATIGRAPHY

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Various recent diatom species from Norwegian Sea-surface water have been isolated and cultured under controlled conditions (e.g., defined water temperature, $\delta^{18}O$-H_2O, light, nutrients).

For comparison purposes pure diatom samples (*Ethmodiscus rex*) from Antarctic sediments were analyzed for their oxygen isotopic composition. Applying the standard method, extremely positive oxygen isotope values were found for this sediment material ($\delta^{18}O$= 44.3 ± 0.3‰ rel. SMOW). This strong isotopic fractionation is caused by the low temperature of the Antarctic sedimentary environment. However, if the standard method is applied on recent diatoms which grew under comparably low temperatures (0 to 6°C), much lower oxygen isotope values (commonly between 25 and 35‰) are measured. Furthermore, the reproducibility of the oxygen isotope analyses of recent material is very poor. Either secondary oxygen isotope exchange during sample preparation and/or silica formation out of isotopic equilibrium with the water is responsible for the relatively low isotopic fractionation.

A final conclusion cannot be made yet as dewatering experiments at different temperatures and various oxidation and extraction technics to remove organic matter prior to isotope analysis are still continuing. However, the present results suggest primary isotopic disequilibrium conditions during formation of the silica fraction fluorinated (commonly between 20 and 30‰ of the original sample). These results may have an important bearing upon the applicability of diatom isotope stratigraphy.

CRETACEOUS STRATIGRAPHY OF THE EXMOUTH PLATEAU, NE INDIAN OCEAN

R. Boyd (Geology Dept., Univ. of Newcastle, NSW, Australia) and Z. Huang

ODP Drilling and previous industry exploration provide information on sedimentation in the Cretaceous sediments of the Exmouth Plateau, NE Indian Ocean. Early Cretaceous sediments of the Barrow Group represent the progradation of a 1700 m thick clastic wedge northwestward across the Exmouth Plateau. Source region and progradation directions of the Barrow Group have been determined by analysis of clinoform dip directions calculated at the intersection of seismic reflection lines. Sedimentation in the Barrow Group has been analyzed by seismic stratigraphic methods and 3-D isopachs generated for 6 time slices in the clastic wedge. Results of these analyses indicate sediment was supplied across an alluvial plain to a delta and often directly into a contemporaneous submarine fan system. Sedimentary environments and systems tracts in the Barrow Group seem to be determined by fluctuations in sediment supply, as well as changes in base level derived from tectonic and/or eustatic causes.

Late Cretaceous sediments are mainly composed of pelagic marls and oozes and display cyclic sedimentation in alternating decimeter-scale light and dark bands. Geochemical and X-ray analyses of these sediments indicate the cycles are due primarily to variations in the clay and carbonate content of the sediments. Walsh spectral analyses of time series measurements of sediment units indicate the cyclicity is of Milankovitch frequency and can be explained by a model in which supply of clay minerals is controlled by climatic processes.

COMPARISON OF Cd AND $\delta^{13}C$ EVIDENCE FOR GLACIAL/INTERGLACIAL PALEOCHEMICAL DISTRIBUTIONS

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Data on the Cd content of benthic foraminifera shells from the most recent glacial maximum (and selected continuous records) have been obtained from 65 sites throughout the global ocean. The cadmium content of deep Antarctic waters was about the same during glacial and interglacial times, and remains lower than in deep waters of the Eastern Tropical Pacific. This result is discordant with $\delta^{13}C$ data showing a shift towards lighter values (in excess of the shift in the global mean) during glacial times, which were as light or lighter than in the Eastern Tropical Pacific at that time. The cadmium content of Northern Indian Ocean above 2500 m was about 40% lower than in the modern ocean. This result is confirmed both by 3 species of calcitic and one species of aragonitic benthics. This result confirms previous conclusions based on carbon isotope data, strengthens confidence in estimates for the depth-dependence of Cd uptake by calcitic benthic foraminifera, and implies a new source of nutrient-depleted intermediate water to this region. A 20-30% lowering of the Cd content of glacial age deep waters of the Northwest Pacific is implied by the data, and glacial Cd levels in this region are lower in Cd than glacial age deep waters of the Eastern Tropical Pacific. This result implies a new source of nutrient-depleted water to this region and is discordant with some $\delta^{13}C$ data which indicates no change in the nutrient content and that the Northwest and Eastern Tropical Pacific had similar $\delta^{13}C$ values. This conclusion must be considered tentative until better core top evidence from this region can be obtained, however.

$\delta^{13}C$ and Cd data are concordant in indicating that intermediate waters of the North Atlantic are somewhat nutrient-depleted compared to today and clearly depleted compared to deeper waters and that deep waters of the North and Tropical Atlantic are enriched in nutrients relative to today.

New high-resolution downcore records from the South Atlantic (at the NADW nutrient-minimum depth) and the Eastern Tropical Pacific for the past 250,000 years will be presented. Surprisingly, the South Atlantic record indicates that NADW has been present at that site throughout most of this period (contrary to inferences drawn from $\delta^{13}C$ data), and Cd variability occurs dominantly at the precession frequency, with minimum NADW in phase with maximum Northern Hemisphere summer insolation.

"OXYGEN MINIMUM ZONE INTENSITY" - A NEW METHODOLOGY FOR SEMI-QUANTIFICATION BASED ON OSTRACODES (UPPER CRETACEOUS-SOUTH TETHYS MARGIN

E. Braccini (Dept. de Géologie et Oceanologie, Univ. Bordeaux I, France) and J.P. Peypouquet

In the Djebel-Dyr section, a recent work-based on ostracode fauna analysis (Braccini & Peypouquet, l99l) indicated that Algerian South Tethys Margin paleohydrology was controlled by coastal cyclic paleo-upwelling until Cenomanian to Eocene.

Between Upper Santonian and Lower Eocene, we have correlated eleven ecozones (determined by ostracode faunas) with eleven three-order eustatic

cycles (Haq et al., 1987). We also specify positive correlations between eustatism, upwelling and Oxygen Minimum Zone (OMZ).

We propose to: 1) elaborate the theorical model for semi-quantification of OMZ intensity. This **new methodology** is based on actual works about ostracode shell variability (Tolderer-Farmer, 1985; Abe, 1988; Peypouquet et al., 1988). According to Peypouquet's polymorphism concept, reticulation and spinosity analysis reflect carbonate and oxygen saturation at the water-sediment interface. We have modeled the ostracode response to five OMZ intensity levels in relationship with upwelling.

2) apply this new methodology to some selected ostracode species from the section until the Upper Santonian to Upper Maastrichtian. We are attempting to evaluate the evolution of the OMZ intensity in relation with coastal, wide-spread paleo-upwelling.

3) show positive correlations with paleoproductivity increase, OMZ widespread and eustatic cyclicity.

4) a paleoclimatical interpretation.

BIOGEOCHEMICAL CYCLE OF BARIUM IN THE SOUTH ATLANTIC

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High concentrations of barium characterize deep-sea sediments underlying zones of higher biological productivity. The geochemical cycle of barium seems to be controlled by biomass. For a better understanding of the barium/barite signal as a productivity indicator surface samples and sediment cores from the South Atlantic were investigated.

Based on barium measurements of surface sediment samples accumulation rates of barite have been calculated within different oceanographic zones in the South Atlantic. High accumulation of barium was found in the Antarctic Zone south of the Polar Front. North of the polar front barium accumulation rates decrease rapidly. The maximum accumulation rate of barium and aluminium were found in sediments of the diatom ooze belt.

Sediment cores were taken on a transect crossing the polar frontal Zone (43°S to 52°S). Barium concentrations were normalized to the concentrations of aluminium as a component of terrigeneous input. The Ba/Al-values range from 2000 x 10^{-4} south of the polar front to 250 x 10^{-4} north of the polar frontal Zone. Interglacial times are characterized by high Ba/Al-ratio whereas the ratio decreases during glacial times. Higher barium flux during interglacial times was interpreted by higher export productivity.

IMAGING THE PHYSICAL PROPERTIES OF DEEP SEA SEDIMENTS BY FULL WAVEFORM TRANSMISSION SEISMOGRAMS ACROSS GRAVITY CORES

M. Breitzke (Universität Bremen, Germany) and V. Spieß

A high-resolution ultrasonic P-wave logging system has been developed to image the variability of physical properties in deep sea sediment cores. In contrast to conventional P-wave logging systems, as for instance the P-wave logger used onboard ODP cruises, full waveform transmission seismograms are recorded parallel to the bedding plane in 1 to 3 cm depth intervals. They show distinct variations in their signal shape and frequency content depending on sediment type and composition.

The transmission seismograms are first analyzed to derive the commonly used logging parameters: An evaluation of the first arrivals yields P-wave velocity logs, and a determination of the maximum amplitudes provides information on the attenuation characteristics.

In addition, the complete transmission seismogram section is processed with respect to its frequency content and instantaneous seismic attributes to enhance the contrast between uniform and stratified parts of sediment sequences. Instead of using conventional wiggle traces for the seismogram display variable density or pixel plots combined with an appropriate color-encoding allow to present the condensed full waveform information on a handy scale.

As an example, results of a gravity core from the equatorial Mid-Atlantic Ridge, which is characterized by several turbidite layers, are presented. A comparison of the transmission seismograms and their amplitude spectra with X-ray and core photographs illustrates the transition of the spectral energy from high- to low-frequency bands within the graded turbidite layers. The relative amount of high- and low-frequency components is obviously controlled by the average sediment grain size, as is evident from a sand content log.

The computation of instantaneous seismic attributes, originally developed for seismic stratigraphy purposes, here provides valuable lithological information. Instantaneous amplitudes reveal a weak attenuation for fine-grained clayey horizons and a strong attenuation for coarse-grained sandy intervals. Plots of the instantaneous phase clearly illustrate the continuity of homogeneous sediment sequences and mark lithological changes by abrupt phase jumps. Instantaneous frequency displays emphasize the turbidite layers as low-frequency depth intervals.

IMPROVED BIOSTRATIGRAPHIC DATING USING PROGRESSIVE GRAPHIC AGE-DEPTH CORRELATIONS OF DSDP/ODP SITES IN THE ATLANTIC OCEAN

W. Brenner (GEOMAR, Kiel, Germany) and T.C.W. Wolf

The development of age-depth models is a common method for summarizing stratigraphic data for a geological record in order to achieve a more detailed and accurate time-scale which can then be used to express the sedimentation history of a geological section. Biostratigraphy has an important place in many areas of historical geology, and in the past decade biostratigraphic methods using computation to calculate enormous data sets from different species has evolved so far that geologists are able to produce stratigraphic frameworks in which a single species data point has the potential for reconstructing age estimates for the geological record.

The intent of this paper is to focus on the development of a continuous age-depth model including data for bolboforma, coccoliths, diatoms, dinoflagellates, planktic foraminifers, radiolaria, silicoflagellates and magnetostratigraphic data from 18 DSDP/ODP sites in the North Atlantic. This information gives us an indication of the relationship between the depth of a section and its chronological age as a method of absolute age calibration on a joint stratigraphic basis.

This data set was processed using Shaw's graphic correlation method as well as the probability of a direct age/depth correlation graphics method. In spite of the various procedures used, both methods, which in the case of the Shaw plot, is based on interpolations of an ideal correlation line and, in the case of the probability age/depth correlation graphic, is based on a minimalization or maximization of the absolute ranges of individual taxa, only slight variations (relative error < 4%) were able to be determined by comparing bioevent ages of the most common taxa. Larger deviations in taxa described only in one or two drill holes are due to the fact that these taxa tend to represent local, that is, smaller distribution ranges in Shaw's method.

THE EARLY DIAGENETIC FORMATION OF "BARITE FRONTS"

H.-J. Brumsack (ICBM, Oldenburg Univ., Germany)

Sediments that are deposited in areas of high biological productivity are often enriched in specific major and minor elements. In case of diatomites, e.g., biogenic silica and Ba are accumulating at the sea floor. Since biogenic silica is dissolving in the corrosive deep waters, only the enhanced levels of Ba seem to document productivity events in the geological record. Here some data are presented that demonstrate, that these Ba enrichments are not necessarily related to productivity spikes alone. Instead, the Ba depth distribution seems to be much more influenced by microbial activity in the sedimentary column than previously thought.

The Ba concentration in marine pore waters is governed by the solubility of barite. As long as sulphate is present in significant amounts, biogenic barites will not dissolve. But in rapidly accumulating sediments that contain organic matter, rather steep sulphate gradients will be established in the interstitial waters and barites will start to dissolve at near-zero sulphate concentrations. In this case, the Ba levels in the pore waters may be more than a factor of 1000 higher than in sea water. Examples from the Gulf of California (Mexico) and the Japan Sea are shown, where Ba concentrations in pore waters are very high below the zone of sulphate reduction.

During stops in sedimentation or drastic changes in sedimentation rate, barites may diagenetically precipitate as concretions in the depth range where sulphate levels are near zero and dissolved Ba increases. Sulphate will be provided by diffusion from the sediment/seawater interface, whereas Ba originates from dissolved biogenic barites below the sulphate reduction zone.

Sulphur isotopes provide a useful tool to distinguish barites formed diagenetically under conditions of sulphate depletion due to microbial activity from those which are precipitated when Barich solutions from cold seeps or hydrothermal activity enter sea water. In the latter case the sulphur isotopic composition of seawater sulphate should be reflected ($\delta^{34}S$ around +2 ‰ rel. CDT), whereas diagenetical barites should mirror the "heavy" ($\delta^{34}S$ between +30 and +80‰ rel. CDT) sulphur isotopic composition of the residual pore water sulphate pool. Diagenetic "barite fronts," therefore, are characterized by a "heavy" sulphur isotopic composition. Examples from Quaternary and Cretaceous sediments are shown.

VARIATION IN SEDIMENT COMPOSITION OF LEG 104 (SITES 642B AND 643A) AS AN INDICATOR OF PALEOENVIRONMENTAL CHANGES DURING DISCONTINUITIES IN THE LATE MIOCENE FOSSIL RECORD

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Samples were taken from ODP Leg 104, Sites 642B and 643A situated on the Vøering-Plateau. Sediments there consist of Neogene pelagic material. Studies included grain-size distribution, carbonate and TOC determination as well as XRD analyses.

The stratigraphic position at both locations was the same, making it possible to compare material of one specific interval from two different cores with similar facies and geographic position.

The focus is on sections with biostratigraphic discontinuities that might be seen as hiatuses. During these intervals there are changes in sedimentation processes. Clues for climatic variability are alternating ratios of the silicious versus the carbonate fossil content. We found differences in the amount of volcanic material. It seems that ecologic variables are reflected in the total bioproduction rate.

The emphasis of our work is on the understanding of changes of the paleoenvironment concerning discontinuities in the fossil record and the formation of hiatusses.

SEASONAL FORAMINIFERAL FLUX IN THE FRAM STRAIT AND GREENLAND SEA

J. Carstens (Universität Bremen, Germany) and G. Wefer

Foraminiferal fluxes >63 µm were monitored at three sites for three years under ice-free and permanently ice-covered stations in the Fram Strait (79°N) and Greenland Sea (75°N) using time-series sediment traps.

The foraminiferal flux shows a strong seasonal pattern under ice-free conditions off Spitsbergen, whereas a station at the same latitude (79°N) off Greenland under permanent ice cover showed no signs of seasonal sedimentation. The yearly foraminiferal flux under permanent ice cover is 20 times lower than under ice free conditions.

Seasonal variations are observed in the faunal composition, with *N. pachyderma* exhibiting its peak abundance in late July/early August, followed by *G. quinqueloba* in late August. Species of *Globigerinita* have their maximum abundance in October (*Gta. uvula*) and November (*Gta. glutinata*). There are also obvious differences in faunal composition among the three sites: off Spitsbergen, the fauna is dominated by *G. quinqueloba*, while at the two other sites *N. pachyderma* and *G. quinqueloba* are equally abundant, and the number of *Globigerinita* species is reduced. At these sites the seasonal faunal succession is also less pronounced.

The faunal succession is accompanied by seasonal changes in the mean test size of *N. pachyderma* and *G. quinqueloba*, with largest tests being deposited in summer and the smallest in winter/early spring.

$\delta^{18}O$ VALUES OF *N. PACHYDERMA* TESTS COLLECTED WITH SEDIMENT TRAPS IN THE FRAM STRAIT AND THE GREENLAND SEA

J. Carstens (Universität Bremen, Germany) and G. Wefer

Oxygen isotope ($\delta^{18}O$) values are determined for tests of the planktonic foraminifer *N.pachyderma* from sediment-trap samples (see poster, Carstens & Wefer) in the Fram Strait and the Greenland Sea.

Specimens from Station SP (79°N) located within the West Spitsbergen current, show $\delta^{18}O$ values between 2.7 and 3‰ (PDB), but exhibit no seasonal pattern, although temperature changes of about 3°C were recorded throughout the year. Station FS (79°N) under permanent ice cover had the most noisy record, with values varying between 2.4 and 3.1‰ and no seasonal trend. Station GS (75°N) in the Greenland Sea had the heaviest values with 3.4 to 3.8‰.

We believe that the $\delta^{18}O$ values in the Greenland Basin are controlled by temperature, while those in the Fram Strait are controlled by the $\delta^{18}O$ content of the water masses. During winter the $\delta^{18}O$ values at Station SP are influenced by the southward moving ice margin transporting relatively isotopically light water masses from the Arctic Ocean to this site, and this influence is much stronger than the lower winter temperatures.

The noisy record at site FS under permanent ice cover is believed to be a real signal, reflecting the highly variable influences of:

1. the cold, low-salinity East Greenland current transporting melt- and freshwater out of the Arctic ocean, and
2. the warmer, but more saline Atlantic waters masses contributed by the return Atlantic current.

MICROPALAEONTOLOGY OF BOREAL LOWER CRETACEOUS CYCLES (APTIAN/ALBIAN) IN NORTHERN GERMANY

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Within the APTI-CORE/ALBI-CORE projects, the sedimentary, biotic and geochemical cycles of the Upper Boreal Lower Cretaceous were investigated for two time intervals: Middle Aptian (Hoheneggelsen and Evern), Middle/Late Albian (Kirchrode 1/91 well/BGR).

Marine sediments of the upper Boreal Lower Cretaceous of northern Germany are monotonous and consist of dark-colored marlstones and marly claystones. They are characterized by carbonate fluctuations which can be correlated with different microfaunal assemblages. It is assumed that carbonate content and microfaunal types are controlled mainly by global mechanisms.

Within the Middle Aptian (Hoheneggelsen and Evern), sediments containing large amounts of planktic organisms (planktic foraminifers, calcareous nannoplankton) were deposited during a warm and relatively dry period. They are followed by sediment dominated by high terrigenous input, decreased carbonate content and microfossil assemblages with few or no planktic organisms. Subsequently, more uniform conditions led to more stable conditions in the water column. These sediments indicate a humid-pluvial period. Waters poor in carbonate also influence the planktonic foraminifers and the calcareous nannoplankton, but do not change the general composition of the microfossil assemblages. In the later part of the cooler period, other paleoenvironmental parameters become valid, as indicated by the excellent aragonitic preservation of gastropods. Later, sediments with high carbonate content reappear. It is assumed that the dark sediments at Hoheneggelsen and Evern correspond to the cool period of the *Globigerinelloides algerianus* Zone, as postulated by Weissert and Lini (1991).

The 240 m thick sequence of Middle/Late Albian age (Kirchrode 1/91 well/BGR) was deposited during a 2.5-4 m.y. period according to nannoplankton biostratigraphy. These monotonous sediments are olive-grey claystones, alternating with grey marls. Rare lithologic changes, variations in borehole logs and grey-shade-scanner records, as well as changing contents of the carbonate and macro- and microfossils are interpreted as periodic or cyclic changes representing parasequences and possibly major sequences. It is assumed that the different composition of sediments and of microfossil assemblages deposited under relatively stable paleoceanographic conditions represent dilution or productivity fluctuations resulting from global and regional changes. The initial results are presented.

POPULATION COUNTS OF PLANKTONIC FORAMINIFERA AT FOUR EQUATORIAL PACIFIC SITES

B. Chaisson (Univ. of Massachusetts, Amherst, USA)

Planktonic foraminifera in the >125 µm fraction at ODP Sites 852 (5°20' N, 110° 5' W) and 847 (0° 6' S, 95° 5' W) in the eastern equatorial Pacific and ODP Sites 806 (0° 19' N. 159° 22' E) and 807 (3° 36' N, 156° 14' E) were counted and classified according to species. Sites 847 and 806 are beneath upwelling zones, while Sites 852 and 807 are beneath the zone of convergence along the boundary of the South Equatorial Current and the North Equatorial Counter-current.

Globigerina species descend to a nadir in the Lower Upper Pliocene before rebounding at all four sites subsequent to the closing of the Panamanian Seaway (3.8-3.2 Ma). At Sites 806, 807, and 847 the decline of *Globigerina* is accompanied by an increase in surface dwelling *Globigerinita glutinata.* In the west thermocline dwelling *Neogloboquadrina acostaensis* re-expands after dwindling through the Lower Pliocene, while at Site 847 it declined rapidly in the Lower Upper Pliocene.

Subsequent to the onset of northern hemisphere glaciation (2.4 Ma), the reverse is apparent: surface dwelling *Globigerinoides* increased in abundance at Sites 806 and 807, while no increase in this genus' numbers is observed in the eastern sites. Instead, thermocline dwelling *Neogloboquadrina dutertrei* expanded greatly in the east, and at the western sites it expanded modestly through the same interval.

THE STABLE ISOTOPE RECORD OF DEEP AND INTERMEDIATE WATER MASSES IN THE SOUTHERN HEMISPHERE: 0-30,000 YEARS B.P.

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An estimated two thirds of the modern ocean below the thermocline originates in the Southern Ocean, a figure which puts into perspective the considerable climatic and geochemical importance of Southern Ocean deep and intermediate water formation processes. Stable isotopic records of benthic and planktonic foraminifera represent one of the few means for tracing changes . In these processes over climate cycles, and although the number of isotopic records for the Southern Ocean is limited (because foraminifera are not abundant in most Southern Ocean sediments), it is now possible to synthesize available isotopic data spanning the past 30,000 yrs from a variety of water depths.

The $\delta^{13}C$ distribution of both deep and surface waters was apparently modulated directly by the relative contribution of North Atlantic Deep Water, increasing abruptly from low glacial-age values to high, essentially modern values at about 12.6 kyr (^{14}C years). This shift is made more dramatic by the fact that Circumpolar Deep Water $\delta^{13}C$ values are consistently among the lowest observed anywhere in the glacial ocean, suggesting that the Southern Ocean may have been a terminus of glacial deep-water circulation. However, the tight coupling of planktonic and benthic foraminiferal records demonstrates that south of about 40°S, communication between surface and deep waters was always maintained. Records from margin sediments bathed in Antarctic Intermediate Water suggest that the $\delta^{13}C$ history of this water mass was unique. Glacial to interglacial $\delta^{13}C$ contrasts at intermediate to mid-depths are relatively minor, in direct contrast to the large changes (1‰) observed in the surface and deep water records.

The extent of this discrepancy provides insight to changing zones of biological productivity and air-sea exchange of CO_2 near the Antarctic Polar Front, the source region for Antarctic Intermediate Water.

^{14}C-dated $\delta^{18}O$ records represent a promising avenue for documenting the timing and magnitude of Antarctic ice-sheet melting over the last deglaciation. Unlike records from the North Atlantic, the glacial-interglacial $\delta^{18}O$ amplitude in the deep Southern Ocean is small enough to rule out a substantial mean temperature shift, yet several large, correlative $\delta^{18}O$ anomalies are apparent which are most likely related to Antarctic meltwater.

THE 0 TO 3.5 MA BENTHIC OXYGEN ISOTOPE STRATIGRAPHY AT ODP SITE 758, BAY OF BENGAL

J.-J. Chen (Dept. of Geological Sciences, Brown Univ., Providence, RI, USA), J.W. Farrell, D.W. Murray, and W.L. Prell

We present an oxygen isotope stratigraphy from the benthic foraminifera *Cibicides wuellerstorfi* that spans the past 3.5 my. These data are from Ocean Drilling Program Site 758, located atop the Ninetyeast Ridge in the northeast Indian Ocean (5° 23'N, 90° 21'E, 2924 m) The record has approximately a 6 ky sample interval and is continuous, as verified by the construction of a composite stratigraphy from two holes drilled at offset depths.

The age model for the past 0.8 My is constructed by correlating the Site 758 oxygen isotope record to the SPECMAP Stack. Spectral analysis of the record using a preliminary time scale based solely on magnetic reversal stratigraphy indicates that the 41 ky cycles dominate within the 0.8 to 3.5 Ma interval. Based on this observation, we abandoned the magnetic time control and tuned the filtered oxygen isotope record to the earth's orbital obliquity time series (Berger and Loutre, 1991) that is based on astronomical theory, and is independent of the magnetic-reversal time scale. For the 0.8 to 3.5 Ma interval, the chronology stems from the match between the 41 ky variations in the isotope record and obliquity record phase-lagged by 9 ky (Imbrie and Imbrie, 1980). With this astronomically-tuned time scale, we examine the evolution of periodic changes in climate.

From 3.5 to 2.4 Ma, the 41 ky periodicity dominates, and a long-term increase in oxygen isotope values is observed, suggesting a combination of cooling deep waters and increasing ice volume. Our results support the finding of Raymo et al. (1989) that prior to 2.4 Ma, the size of the Northern Hemisphere ice sheet was only 25% the size during the Late Pleistocene. Between 2.4 and 0.8 Ma, ice sheet size was 50% of that during the Late Pleistocene. .Since 0.8 Ma, when the ice sheets were largest, the dominate ice volume periodicity has been 100 ky.

LATE QUATERNARY FAUNAL RECORD OF SEA-SURFACE CONDITION IN THE EASTERN TROPICAL INDIAN OCEAN; IMPLICATION FOR ATMOSPHERE-OCEAN CIRCULATION CHANGES

M.-T. Chen (Dept. of Geological Sciences, Brown Univ., Providence, RI, USA), J.-J. Chen, and W.L. Prell

Variations in planktonic foraminifer fauna recorded in marine sediments recovered at ODP Site 758 (5° 23.05'N, 90° 21.67'E, 2924 m, ~6 k.y. sampling interval) in the eastern tropical Indian Ocean are interpreted as reflecting climate changes over the past 800,000 years. The drilling site is presently located in a seasonally stable region of the Indian Ocean Warm Pool (IOWP) with connection of western Pacific thermocline waters via Indonesian throughflow. Thus, the faunal record at Site 758, in large part, monitors the global climate influences on the sea-surface condition in this region and is sensitive to the changes in basin-scale circulation patterns in the tropical Indo-Pacific Ocean.

The foraminiferal faunal data were quantitatively transformed into Sea-Surface Temperature (SST) and salinity (SSAL) based on the modern calibration of Indian and Pacific coretop data. We correlate the oxygen isotope curve analyzed from benthonic foraminifer *Planulina wuellerstorfi* with SPECMAP $\delta^{18}O$ stack to develop the age control of the record. Within the 800,000 year interval, the estimated SST and SSAL variations exceed the seasonal, as well as regional extremities of SST and SSAL in the modern eastern tropical Indian Ocean. Time series analyses of the SST and SSAL records indicate statistically significant concentrations of variance in orbital and low-frequency bands. Over the past 500,000 years, maximum SST and minimum SSAL are in phase with, or slightly lag, maximum global ice-volume in 100 ky and 41 ky cycles; and in phase with, or slightly lag, maximum radiation (North Hemisphere, June) in 23 ky cycles.

These statistical results suggest that in 100 ky and 41 ky cycles, the change in basin-scale patterns of tropical atmosphere-ocean circulation associated with glaciation cycles must play a role in the tropical climate history. The 23 ky cycles of the tropical Indian SST and SSAL may respond directly to the variation of local radiation. The dominant low-frequency and large-amplitude variations present in the sea-surface condition records imply that effective mechanisms, particularly reorganization of basin-scale patterns of ocean circulation or alteration in other boundary conditions, cause the tropical climate changes.

ORBITAL CYCLICITY IN HIGH-LATITUDE SEDIMENTS: SPECTRAL ANALYSIS OF MULTI-SENSOR, CORE-LOGGING DATA

J. Chi (Special Research Project 313, Kiel, Germany) and J. Mienert

Multi-Sensor, core-logging data (magnetic susceptibility, gamma ray attentuation density, compressional-wave velocity) plotted against depth show cyclic patterns. If these patterns are records of periodic orbital forcing, then they have to conform to its frequencies.

In this study the logging data were time-calibrated using a standard oxygen isotope record. The magnetic susceptibility records were converted to age and show a good correlation between sites in a variety of pelagic sediment provinces.

We represent the spectral analysis of several deep-sea sediment cores retrieved from the Rockall Plateau and the Norwegian-Greenland Sea. The spectrums reveal most of the mean frequencies centered at 19 ka, 23 ka, 41 ka and 100 ka. The predominant period corresponds to 100 ka with large variations in the amplitudes of the peaks. The common characteristics, differences and difficulties in applying spectral analysis to high-latitude, core-logging data will be discussed.

COUPLED STABLE-ISOTOPE AND TRACE-ELEMENT ANALYSIS OF MICROGRAM QUANTITIES OF CARBONATES AS INDICATORS OF MARINE ENVIRONMENTS

(Abstract prepared for the ICP IV workshop on Stable Isotopes in Paleoceanography)

A. Chivas (Research School of Earth Sciences, The Australian National University, Canberra), J.A. Cali, A. Chapman, E. Kiss, J.M.G. Shelley, X. Wang, P. De Deckker, F. Peerdeman, and M.K. Gagan

A new analytical technique that produces $\delta^{18}O$, $\delta^{13}C$, Sr/Ca, Mg/Ca (and potentially $^{87}Sr/^{86}Sr$) results on the same microaliquot (down to ~30 μg) of $CaCO_3$ is being applied to the study of climatic histories in both the lacustrine and marine environments.

The apparatus consists of a Finnigan automated individual-carbonate reaction device (Kiel), wherein a few drops of 107% H_3PO_4 acid are dosed into 44 individual reaction thimbles at 70°C containing the carbonate samples. The originally designed apparatus has been modified both in the Bremen factory and in Canberra to accommodate longer sample thimbles (66 mm) composed of pure silica. The acid is also delivered from a silica reservoir. The required high-purity phosphoric acid currently manufactured in our laboratory has reaction plus reagent blank levels of 14 ppb Ca, 2 ppb Mg and 0.04 ppb Sr. After mass spectrometric analysis of the evolved CO_2, the acid-reaction residues are diluted in each reaction thimble and these thimbles transferred directly to the sample holder of an automated inductively-coupled argon plasma atomic emission spectrometer for analysis of Ca, Mg and Sr contents. The limits of detection for Ca, Mg and Sr are respectively 36, 24 and 32 pg/g (parts per trillion) in solution.

The technique has been applied to situations where decoupling of palaeoclimatic signals provided from trace elements and oxygen isotopes is desirable. For example, in some biogenic marine carbonates, the Mg/Ca ratio is a function of temperature and thus coupled Mg/Ca and $\delta^{18}O$ measurements can

help determine the temperature-related contribution of $\delta^{18}O$ variations and decouple temperature- and ice-volume-related effects. For near-continent corals, coupled Sr/Ca and $\delta^{18}O$ can resolve temperature changes from run-off-related $\delta^{18}O$ (ie monsoonal) variations. The coupled technique is ideal for the study of diagenesis or to screen out diagenetically altered samples if the primary palaeoclimatic $\delta^{18}O$ signal is sought, the latter for example, by monitoring the Sr/Ca ratio in foraminifera.

DRASTIC CHANGES IN NE-ATLANTIC DEEP-SEA SEDIMENTS AND FAUNAS: EVIDENCE OF RECURRENT LATE QUATERNARY ICE SURGES (Part 1)

S. Clasen (Institut für Geologie und Paläontologie, Göttingen, Germany), S. Huon, R. Jantschik, and D. Meischner

In the West European Basin, late Quaternary deep-sea sedimentation is controlled by drastic changes between glacial and interglacial conditions. Interglacial conditions are recorded by depositon of carbonate-rich foraminiferal ooze (FO). Glacial conditions result in deposition of diamicton (DI), rich in ice-rafted detritus (IRD), and with low carbonate content .

Within the sediments of oxygen isotope stages 2 and 3, four horizons of dolomitic marl (DOL) are found. Dolomitic marl occurs in water depths ranging from 3,900 to 5,000 m. This sediment is characterized by unusually low porosity and is denser in X-radiographs than other sediments. Mineralogically, DOL is nearly unaltered tilly material. The carbonate fraction consists of detrital calcite and dolomite as indicated by their low Sr content. Foraminifera are extremely rare. Each set of dolomite layers reveals similar sedimentary structures, physical properties, and mineralogical composition. In DOL 2 and 3, lamination is preserved due to inhibited bioturbation.

Dolomite layers are located between Ash I (10.8 ka) and Ash II (59 ka). The interpolated ages are: DOL 1 = 14 ka, DOL 2 = 20 ka, DOL 3 = 39 ka, DOL 4 = 50 ka. Therefore, they can be used as stratigraphic markers during the last 60 ka throughout the investigated area.

The fine-grained silicate fractions (<2 and 2-16 μm) of the four dolomite layers are characterized by low smectite and high quartz, K-feldspar, plagioclase, and amphibole contents, related to enhanced ice-rafting supply of continental material. The K-Ar ages for these fractions are 800-1140 Ma, in contrast to 350-500 Ma for the FO and DI ambient sediment. These mineralogical and isotopic data reflect supply of Precambrian material from Canada and Greenland and the shut-down of the input of basalt-derived material transported by deep water currents from the icelandic region.

During the last 60 ka, four events of rapid depositon of IRD indicate recurrent late Quaternary ice surges of the eastern Laurentide ice sheet. Massive input of icebergs changed surface water conditions in the North Atlantic Ocean between Labrador and the West European Basin. Subsequently, these conditions caused a halt in production of North Atlantic Deep Water and bottom water became stagnant.

RESPONSE OF THE INDIAN OCEAN MONSOON TO OCEANIC, ATMOSPHERIC, AND GLOBAL ICE-VOLUME CONDITIONS OVER ORBITAL AND SECULAR TIME-SCALES

S. Clemens (Dept. of Geological Sciences, Brown Univ., Providence, RI, USA) and F. Sirocko

Arabian Sea sediments contain biological, biogeochemical, and lithologic tracers of past changes in Indian Ocean summer-monsoon winds and regional aridity. Over orbital time scales (10^{-4} to 10^{-5} years), the monsoonal climate is externally forced by cyclical changes in solar radiation and internally phase-locked to latent heat transport between the southern subtropical Indian Ocean and the Tibetan Plateau. Environmental change associated with changes in global ice-volume is not a primary forcing mechanism of monsoon variability. Global ice-volume variability is, however, a primary factor in determining regional aridity and, hence, atmospheric dust flux to the Arabian Sea.

Over sub-orbital time scales (10^2 to 10^3 years), Arabian Sea sediments record abrupt climatic events which are superimposed upon the longer-term cycles associated with solar radiation forcing. High-resolution C^{14}-dated records reveal a succession of events of less than 300 year duration. Of particular interest is the abrupt decrease in dust flux to the Arabian Sea at 13,000 C^{14} yrs B.P. associated with the very beginning of global sea-level rise and transgression into the Persian Gulf.

HOLOCENE SEA -SURFACE TEMPERATURE VARIABILITY IN THE AGULHAS CURRENT REGION: IMPLICATIONS FOR GLOBAL AND REGIONAL CLIMATES

A.L. Cohen (Archaeometry Lab, Univ. of Cape Town; Climatology Research Group, Univ. of Witwatersrand, South Africa)

The Agulhas current is one of the world's major western-boundary currents and is the dominant ocean-scale feature off the east coast of South Africa. Sea-surface temperature variability and associated changes in current strength (volume flux) significantly affect climate and rainfall over the adjacent sub-continent. South African workers have recently demonstrated a strong positive correlation between anomalously warm (cold) summer surface temperatures in the Agulhas with wetter (drier) seasons over the summer rainfall region today. The influence of the Agulhas Current extends globally. By shedding warm rings into the South Atlantic, it may be a crucial link in global thermohaline circulation.

In this paper, we present the results of a sea-surface temperature reconstruction of the Holocene Agulhas Current using mollusc shells from an archaeological deposit on the eastern Agulhas Bank. Mean temperatures vary considerably between 12,000 and 650 years B.P. with maximum summer and winter temperatures obtaining during the mid-Holocene, approximately 6,000 years ago. Independent data show that climate over the South African summer rainfall region was a great deal wetter 6,000 yrs .B.P. than it is today. Based on present-day observations, we suggest that the generation mechanisms for such events include intensification of the easterly trade winds in the southwest Indian Ocean and southward displacement of the westerly wind belt, a scenario in accordance with current thinking about the Holocene Climatic Optimum in the Southern Hemisphere. Such change in the large-scale wind field probably

increased inter-ocean exchange of water south of the continent with important consequences for global climate.

DISTRIBUTION OF RECENT BENTHIC FORAMINIFERA FROM THE NW ATLANTIC ABYSSAL PLAIN AND CONTINENTAL MARGIN

E.S. Collins (Dalhousie Univ., Halifax, Nova Scotia, Canada), W. Kuhnt, and D.B. Scott

We studied the distribution of living and dead benthic foraminifera in box-core samples along a transect from the abyssal oligotrophic gyre of the Sargasso Sea across the Gulf Stream towards the continental rise in the Baltimore Canyon region. Three different faunal assemblages are distinguished. Assemblages from abyssal oligotrophic sites (Sargasso Sea) are characterized by small infaunal agglutinated species and small delicate unilocular forms such as *Rhizammina algaeformis* and *Komokiaceans*. Benthic assemblages of the continental rise directly underneath the Gulf Stream have higher standing stocks and are dominated by calcareous benthic foraminifera and large unilocular *astrorhizaceans*. Benthic foraminiferal assemblages underneath the zone of cold core rings south of the Gulf Stream differ from abyssal assemblages of the oligotrophic gyre of the Sargasso Sea and from the Baltimore Canyon continental rise in the following features: (1) higher abundance of calcareous benthic foraminifera, (2) higher numbers of living agglutinated foraminifera, (3) special habitat preferences and test morphologies in *Komokiaceans*, (4) rare occurrence of large unilocular astrorhizaceans, (5) common occurrence of attached agglutinated foraminifera.

We speculate that these peculiar features are related to two special environmental conditions underneath the Gulf Stream and the zone of cold core rings: (1) influence of bottom currents, which may be adverse for delicate epifaunal species; (2) for abyssal environments unusually high and steady supply of nutrients and phytodetritus provided by deep currents.

LATE HOLOCENE PALEOENVIRONMENTAL AND SEA-LEVEL RECONSTRUCTIONS ALONG THE SOUTH CAROLINA COASTLINE

E.S. Collins (Center for Marine Geology, Dalhousie Univ., Halifax, Nova Scotia, Canada), D.B. Scott, and P.T. Gayes

Although the southeastern United States has an extensive, low-lying coastal plain with abundant marsh-estuarine systems, these areas had never been investigated for benthic foraminifera. Hence it was difficult to use proven sea-level relocation methods in this region of North America. To overcome this problem, recent benthic foraminifera were collected from Santee Delta, Murrells Inlet and North Inlet (South Carolina) to characterize the modern environments and compare with cores from these localities. High sediment loading from the Santee River system is displayed in both surficial and core samples from this locality. Both Murrells and North Inlets display more typical marsh assemblages with zonations from high to low marsh. From the baseline quantitative distribution data from Murrells Inlet a sea-level curve was constructed which shows a mid-Holocene oscillation previously not reported in South Carolina. The curve from adjacent Santee Delta shows that differential subsidence has

taken place on the Santee Delta, probably as a result of sediment loading, on a similar but smaller scale than the Mississippi Delta.

UPPER PLIOCENE CLIMATIC CYCLES: HIGH-RESOLUTION MARINE POLLEN RECORD FROM CENTRAL MEDITERRANEAN

N. Combourieu-Nebout (CNRS, Paléobiologie et Palynologie, Univ. Pierre et Marie Curie, Paris, France)

High-resolution pollen record from two marine sections in southern Italy (39°N) documents the Upper Pliocene climatic history of the central Mediterranean. Time control is provided by foraminifers, paleomagnetism, $\delta^{18}O$ curves and astronomical calibration of the pliocene sapropels (Hilgen, 1991). 100 samples have been studied in a time interval of about 250,000 years (from isotope stage 100 to isotope stage 89).

Pollen analyses express the modifications of the vegetation belts in a mountain site with the competition of four vegetation units. Several increases of herbaceous open vegetation regularly alternate with developments of subtropical humid forest and reveal the glacial interglacial cyclicity. The vegetation succession (deciduous forest, subtropical humid forest, altitudinal forest, and open vegetation) reflects the climatic evolution from warm and humid interglacial to cold and dry glacial, and indicates a time lag between temperature and moisture variations, as seen in the most recent glacial/interglacial cycles. These vegetation changes, which appear several times, coincide with $\delta^{18}O$ fluctuations recorded on the same samples. Therefore, during the Upper Pliocene, the modifications of the vegetation in the central Mediterranean occur in phase with those of the global climate . Pollen and isotope records shows that isotope stage 94 appears weakly developed in the Mediterranean.

RAPID GROWTH OF DEEP-SEA BENTHIC FORAMINIFERA FROM THE SAN PEDRO BASIN, CALIFORNIA BORDERLAND

B.H. Corliss (Dept. of Geology, Duke Univ., Durham, NC , USA) and K. Silva

An analysis of Rose Bengal stained benthic foraminifera from box cores taken from the San Pedro Basin at about 720 m in April, July, and October, 1988 reveals distinct changes in faunal composition and species abundances. The maximum abundances of >150 µm calcareous foraminifera occurred in July, whereas maximum abundances within the 63-150 µm fraction were found in October. Individual species maxima were found in April, July, or October.

Changes in species abundances between samples can be used to assess the growth rates of a number of taxa. *Buliminella tenuata*, a small species found primarily in the 63-150 µm fraction, has relatively low numbers in April and July and a maximum in both size fractions in October. *Nonionella stella*, a larger species found primarily in the >150 µm fraction, has a maximum in October in the >150 µm fraction, with juveniles absent in the 63-150 µm fraction in July.

The increased abundance of these two species in October is unlikely to be a result of sediment transport because of the pristine nature of the fragile tests and the lack of stratified sediments at the site. The increased abundances can be accounted for by reproduction occurring at the site or a recruitment event in which juveniles were transported into the area as meroplankton, followed in either case by rapid growth during a three-month period. The rapid growth of the foraminifera indicates that the test chemistry will reflect environmental conditions over a relatively short time interval (~months). This observation and the capability of analyzing single specimens suggest that it is possible to determine high-resolution data from foraminifera living in environments similar to the San Pedro Basin where rapid growth occurs. By analyzing a number of species which grow at different times of the year, it should be possible to reconstruct seasonal paleoenvironmental conditions in the deep sea.

PALAEOTEMPERATURE RECONSTRUCTION OF THE WESTERN CORAL SEA THROUGHOUT THE LAST 120 000 YEARS USING CHEMICAL ANALYSES OF BENTHIC OSTRACOD SHELLS.

T. Corrège (Dept. of Geology, The Australian National University, Canberra)

Chemical analyses of modern benthic ostracod valves indicate that there is a relationship between the Mg uptake in the calcitic valves and the temperature of the ambient water (De Deckker et al., abstract). Ostracods collected at different water depths (and hence different temperatures) in the Coral Sea enabled us to construct calibration graphs linking the water temperature to the molar Mg/Ca ratio in the ostracod valves of specific genera. These graphs can then be used to reconstruct water temperatures from analyses of Mg/Ca in fossil ostracods. So far, we have studied two ubiquitous genera, *Krithe* and *Bythocypris*, but pilot work on other genera shows promising results as well.

This method was applied to material from cores taken in the Queensland Trough (western Coral Sea) and spanning the last 120,000 years. Preliminary results from a core taken in the upper part of the Antarctic Intermediate Water (ODP core 822 from Leg 133; water depth 955 m; present-day bottom water temperature 5°C ±0.5°C), indicate substantial change of water temperature during this period. Episodes of cooling, separated by returns to present-day temperature are recorded in the ostracod shell chemistry. Analyses of material from two other cores from the same area (water depth: 1630 m and 2060 m) are under way and results will be presented during the conference. Preliminary observations seem to contradict results derived from oxygen isotopes from the Ontong Java Plateau (Herguera et al. 1991) which indicate that the water temperature above 2000 m did not change during the Last Glacial Maximum. This difference could be explained in 2 ways: first, the oceanographic regime in the two regions (western Coral Sea and Ontong Java Plateau) during glacial times could have been substantially different. Second, water temperatures derived from oxygen isotopes are still relying on the estimation of the ice-volume effect in the isotopic signal, and can therefore be inaccurate. An oxygen-isotope analysis of the Coral Sea material should help resolve these discrepancies.

DISTRIBUTION OF RECENT OSTRACODA FROM THE ARCTIC OCEAN: APPLICATION TO LATE NEOGENE OCEANOGRAPHY

T.M. Cronin (U.S. Geological Survey, Reston, VA, USA), R.C. Whatley, T.R. Holtz, Jr., and A.V. Shuckstes

Many species of marine ostracoda are sensitive indicators of bottom water mass conditions and have potential application to paleoceanography. We examined 45 core-top samples (water depths = 552-4,426 m) from the

Amundsen and Makarov Basins, Lomonosov and Gakkel Ridges, Morris Jesup Rise and Yermak Plateau from the ARCTIC'91 cruise of the RV Polarstern. All yielded ostracodes (total of 25 species); most species have upper and lower depth limits and geographic distributions influenced by water mass characteristics, such as the boundary between intermediate and deep Arctic Ocean water (700-900 m) and (or) physiographic barriers, such as the Lomonosov Ridge. Q-mode and R-mode factor and cluster analyses of the 45 ARCTIC'91 samples and 21 coretop samples from the Canada Basin (Joy and Clark, 1977) reveal 4 main assemblages: an Upper Arctic Deep Water (UADW) assemblage (1,000-3,000 m); a Lower Arctic Deep Water (LADW) assemblage (Canadian and Eurasian Basins); an Eurasian Lower Arctic Deep Water (ELADW) assemblage; and an intermediate depth North Atlantic Layer (NAL) assemblage influenced by inflowing North Atlantic water near the Fram Strait. A major faunal turnover occurs near 3,000-3,500 m, where diverse UADW assemblages are replaced by low-diversity LADW (high % of *C. bronwynae*) and ELADW [*Krithe* and *Cytheropteron alatum* (30-80% and 10-30%, respectively)], assemblages below 3,500 m. These results show that biogenic carbon occurs in the deepest parts of the Eurasian Basin and distinct assemblages inhabit these regions.

We are using core-top results to quantitatively analyze late Neogene water mass history recorded in ARCTIC' 91 long cores. Preliminary results for core 2200 (Morris Jesup Rise, 1,073-m water depth) show complex faunal successions with frequent changes in bottom water conditions throughout the core. The interval 388-303 cm (tentatively correlated with Late Pliocene lithologic zone AB from the CESAR 14 core; Scott et al, 1989) was the first major introduction into the Arctic of calcareous microfaunas coinciding with the end of seasonally ice-free conditions and global cooling at 2.4 Ma. With adequate dating, better correlation of Arctic and North Atlantic Ocean history can be obtained.

QUANTITATIVE RECONSTRUCTION OF PLIOCENE AND QUATERNARY OCEANOGRAPHY, SEA OF JAPAN, BASED ON MARINE OSTRACODA

T.M. Cronin (U.S. Geological Survey, Reston, VA, USA), N. Ikeya, A. Kitamura, and T. Kamiya

The modern distribution of marine ostracoda from coastal, shelf, and upper slope environments off Japan were analyzed to determine characteristic assemblages of different water masses. A total of 276 species from about 300 samples were studied. Q-mode CABFAC factor analysis of the 60 most common species reveals distinct assemblages for the following water-mass: west Kuroshio Current (off Kyushu, southern Korean Peninsula), south Kuroshio Current (East China Sea), mixed Oyashio/Kuroshio Currents (off Sendai, NE Honshu), Tsugaru Current (northern Honshu, southern Hokkaido), north Tsushima Current (Sea of Japan off NW Honshu and Hokkaido), south Tsushima Current (Sea of Japan off Honshu), and Soya/Oyashio Currents (Hokkaido, NE Honshu). Each assemblage has characteristic species whose distributions are mostly influenced by summer and winter temperature and, within a region, by sediment type.

Fossil ostracode assemblages from the Tentokuji and Sasaoka Formations of the Akita area, and the Yabuta and Omma Formations near Kanazawa, and the Hiradoko Terrace, Noto Peninsula were compared to modern assemblages. The results indicate the paleoceanographic history for upper bathyal/littoral environments along the Sea of Japan. From about 3.0-1.2 Ma, upper bathyal environments were similar to those in the modern upper Japan Sea Proper Water. A minor influx of cold water ostracode species occurred at 2.5-2.4 Ma. About 1.2 Ma, a more significant influx of cold water taxa occurred in the Sasaoka Formation. Simultaneously, in the middle Omma Formation, a pattern of alternating cool and warm assemblages signifies high frequency/high amplitude glacial-interglacial cycles. Very warm surface water entered the Sea of Japan during the last interglacial period, at about 125 ka.

EFFECT OF CENOZOIC GATEWAY CHANGES ON THE OCEAN CIRCULATION

T.J. Crowley (Applied Research Corp, College Station, USA), U. Mikolajewicz, and E. Maier-Reimer

Even in the absence of climate variations, changes in the solid boundaries of the ocean basins should have caused significant changes in the ocean circulation. We report results from some ocean, general-circulation model experiments which clarify the ocean response to two of the most significant changes in the Cenozoic -- opening of the Drake Passage and closing of the Central American isthmus. All simulations were conducted with present atmospheric forcing. A closed Drake Passage results in a profound reorganization of the ocean circulation. Introduction of a frictional boundary reduces the velocity of the Antarctic current. As there is a geostrophic balance between strength of the current and horizontal pressure gradient across the current, reduction in the strength of the current causes increased outflow of Antarctic waters into the world ocean basin. The changes are so large (factor of three) that eventual upwelling of the Antarctic waters into the North Atlantic suppress formation of North Atlantic Deep Water (NADW). Experiments with both a closed Drake and open Central American isthmus indicate that even after the Drake Passage is open, NADW production is still suppressed due to exchange of low salinity waters between the North Atlantic and North Pacific. Contrary to geological conjecture, opening of the Drake Passage does not result in surface cooling around Antarctica. This result implies that some other factor (CO_2?) is responsible for Antarctic glacial expansion in the Oligocene.

A LITTLE ICE AGE CORAL RECORD FROM THE TROPICAL SOUTH PACIFIC

T.J. Crowley (Applied Research Corp., College Station, USA), T.M. Quinn, and F. W. Taylor

There is virtually nothing known about Little Ice Age climate fluctuations in the tropical South Pacific. Here we report $\delta^{18}O$ and $\delta^{13}C$ results from a coral record (1804-1979) from Vanuatu in the New Hebrides (15°S, 166°E). $\delta^{18}O$ variations of 1.0‰ are too large to be ascribed solely to temperature variations; they are probably a combination of temperature and salinity variations. This conclusion is consistent with location of the record beneath the South Pacific Convergence Zone, in which temperature and precipitation fluctuations are positively correlated. The most significant 19th century cooling occurs from 1835-1865. This response is not synchronous with most northern hemisphere land records and raises questions about global synchroneity of Little Ice Age events. There is an abrupt warming in 1866, after which temperatures oscillate around a mean

that does not vary significantly with time. This abrupt transition may reflect a new type of climate instability involving decadal-scale El Niño processes.

A NEW PALAEOTHERMOMETER: THE MAGNESIUM TO CALCIUM RATIO IN BENTHIC OSTRACOD VALVES

P. De Deckker (Dept. of Geology, The Australian National University, Canberra), T. Corrège, J.M.G. Shelley, and A.R. Chivas

Ostracods are bivalved microcrustaceans that secrete low-Mg calcitic valves; they are ubiquitous in the oceans, although few in numbers, down to the CCD.

Using recent specimens of deep-sea ostracods [collected by T.C.] from the Coral Sea area, we correlated the molar Mg/Ca of individual ostracod valves (weighting 20-50 μg) against bottom water temperature and the water Mg/Ca. Measured temperature ranged between 2° and 6°C.

Although the Mg/Ca of ostracod shells is a function of the Mg/Ca of the water as well as water temperature, we calculated that a change of 0.1 of the Mg/Ca of sea water (that is nevertheless difficult to achieve due to the long residence time of both elements in sea water) could not be detected through the Mg/Ca analyses since it is within the analytical error [when using an ICP or a graphite furnace AA] compared to a temperature change of 1°C. For species belonging to the genus *Krithe*, a change of temperature from 1°C to 2°C is registered by a 33% increase in the Mg/Ca of the ostracod valve. Thus, difference in water Mg/Ca can be ignored, and temperature considered to be the prime factor for any Mg/Ca change in the ostracods.

Analyses of fossil ostracods from a Late Quaternary core from the Tasman Sea, western Pacific (DSDP 593, water depth 1078m) and another from the eastern Indian Ocean (ODP 760; water depth 1969m) point out to bottom water temperature changes comprobable with those estimated from the $\delta^{18}O$ analyses of benthic foraminifers (Chappell & Shackleton, *Nature* 1986).

Mg/Ca analyses of individual ostracods from DSDP core 590 [water depth: 1391m; with a record extending down to the earliest Miocene, and for which pore-water chemical data from Baker (*DSDP Init. Rep.* Leg 90) indicate diagenetic changes of Mg/Ca downcore] apparently show ostracod shells unaffected by diagenesis, but principally reflecting a temperature change through time.

PALAEOENVIRONMENTS ABOVE THE EXMOUTH PLATEAU, WESTERN AUSTRALIA, FOR THE BRUNHES CHRON

P. De Deckker (Dept. of Geology, The Australian National University, Canberra), P. Wells, A.R. Chivas, J. Cali, T. Corrège, D. D'Costa, J.M. Shelley, J.M.G. Shelley and W.S. Wickremeratne

ODP core 760 [lat. 16° 55.32 S, long 115° 32.48 E; water depth: 1969 m] has been analyzed in detail for the following: mineralogical composition, aeolian dust content, planktic and benthic foraminifera, stable-isotopes of selected planktic foraminifer species, ostracod fauna and trace-elements (Sr and Mg) of specific ostracod taxa, and pollen and spores.

The summer and winter SST reconstructed using foram transfer functions indicate small temperature deviations between glacial and interglacial episodes as already recognized by CLIMAP for the LGM on the northwest shelf. This is in marked contrast with other core sites along the western Australian coast (Wells, unpublished data) where significant temperature ranges have been determined between the present and the LGM.

Benthic foraminifers also provide information on changes of water masses between glacial and interglacial episodes. Ostracod shell chemistry indicates fluctuations of bottom-water temperature that coincides with changes of some benthic foraminifer taxa.

For nearly the entire Brunhes Chron, the $\delta^{18}O$ record usually runs in parallel with the planktic foraminifer data, the SST reconstructions based on the planktic foraminifers and the ostracod shells chemistry data. Some time lags are noticeable for some episodes, but the pattern is not consistent.

The abundance of arboreal pollen is highest for glacial intervals. This implies that the source of pollen was closer to the coring site and is justified knowing the extent shallow depth of the continental shelf in the area.

The grain size analysis of the non-carbonate fraction in the core indicates a substantial percentage of grains >10 µm that are considered to mostly represent an aeolian component. The peaks of the fraction >10 µm nearly always coincide with the periods representing low SST, and isotopically heavier $\delta^{18}O$ values. This correspondence further confirms the significance of aridity, and consequently deflation on the mainland - and most probably also of the exposed continental shelf - during "glacial" episodes.

CENOZOIC CHEMICAL MASS BALANCES IN THE WORLD OCEAN

M.L. Delaney (Institute of Marine Sciences, Univ. of California, Santa Cruz, USA)

Phosphorus (P), supplied to the ocean from continental weathering, is a limiting nutrient for oceanic primary productivity and organic carbon burial on geologic time scales. Oceanic P inventories depend on input/output fluxes and on oceanic circulation. Little is known about the history of P fluxes during the Cenozoic, nor are there direct records of oceanic dissolved P inventories. Two lines of reasoning about oceanic mass balances are significant in this regard.

First, increasing river fluxes during the Cenozoic have been invoked to explain the observed variations for several tracers of oceanic geochemistry. Although mass balance model results for individual tracers (e.g., strontium-to-calcium ratios and strontium isotope ratios in calcareous sediments, germanium-to-silica ratios in opaline sediments, depth of the calcite compensation depth, accumulation rates for biogenic sediments may disagree about the magnitude and timing of changes in dissolved river fluxes, there is general agreement that these fluxes have increased worldwide, with plausible mechanisms suggested (e.g. the effects on weathering rates of sea level, glaciation, and/or tectonism). Second, the carbon isotope signature of dissolved inorganic carbon in the ocean has decreased, especially over the past 15 m.y. Interpretations of this decrease using mass balance models of the carbon geochemical cycle, with a variety of assumptions, indicate that organic carbon burial in marine sediments has decreased over this time interval, either in absolute terms or relative to calcium carbonate burial. Independent geochemical models based on relative sedimentary rock abundances reach similar conclusions.

There is an apparent contradiction between increasing river fluxes of phosphorus, expected to drive increasing organic carbon burial, and observations indicating decreasing organic carbon burial. The implications of this contradiction for phosphorus fluxes and inventories will be examined with oceanic mass balance models by varying phosphorus burial rates in sinks with different C:P ratios, with results compared to existing indirect evidence about P variations.

GREAT BARRIER REEF CORAL AND HALIMEDA CADMIUM-TO-CALCIUM RATIOS DURING THE HOLOCENE

M.L. Delaney (Institute of Marine Sciences, Univ. of California, Santa Cruz, USA), L.J. Linn, E.R.M. Druffel, S. Griffin, and P.J. Davies

Nutrient supply to the Great Barrier Reef (GBR; Queensland Shelf, Australia) may have changed during the Holocene driven by sea-level and bathymetry changes and resultant varying upwelling intensity. Nutrient history in this region may thus have exerted significant control over the Holocene growth of coral reefs and accumulation of bioherms from the aragonite plates deposited by *Halimeda*, a calcareous green alga. Due to similar geochemical behavior for cadmium and phosphate in the water column and for cadmium and calcium in aragonite deposition, cadmium-to-calcium ratios in corals have proved to be powerful tools for deciphering seasonal, annual, and event changes in upwelling intensity in other regions. We report here our investigations into Cd/Ca records in contemporary and Holocene GBR *Halimeda* and coral aragonite as the framework for testing these hypotheses about nutrient control of reef development.

We discuss "calibration" of aragonite Cd/Ca ratios using water samples and contemporary *Halimeda* and coral heads (*Porites* spp.) from John Brewer and Bowden Reefs, two mid-shelf reefs in the central GBR. To focus on long-term variability, we present Cd/Ca ratios for Holocene coral samples from Ribbon Reef No. 5, and outer-shelf barrier reef in the northern GBR, and for *Halimeda* samples from North Bank (a bioherm immediately inshore of RR No. 5). To focus on short-term variability, we discuss Cd/Ca results for coral samples from two southern GBR reefs: a 10 y section from One Tree Reef (7440 ybp) and selected samples over a 100 y interval (AD 1660-1760) from Abraham Reef. We compare the latter results to carbon-14 indications of upwelling intensity.

The role of intra- and inter-annual variability, as well as that of location in the reef complex, on Cd/Ca ratios is addressed on these various time scales. In addition, we discuss other trace (Mn/Ca) and minor element (Sr/Ca and Mg/Ca) ratios in these samples, as well as the impact of diagenetic alteration.

SEDIMENTARY CYCLES IN THE JAPAN SEA (ODP-LEG 128): IMPLICATIONS FOR CHANGES IN PALEOCLIMATE AND PALEOCEANIC CIRCULATION THROUGH LATE CENOZOIC TIMES

M. Dersch-Hansmann (Alfred Wegener Institute, Bremerhaven, Germany), R. Stax, and R. Stein

The Japan Sea as one of the major Pacific marginal seas plays an important role in terms of a highly sensitive hydrographic system to both climatic and paleoceanographic changes. These changes are reflected in distinct long- and short-term variations in the sediment flux and composition at ODP - Sites 798 and 799.

The long-term fluctuations in the siliciclastic sediment composition do probably reflect a gradual change to more arid climatic conditions in the source area of the material. The distinct increase in accumulation rates of total organic

carbon, quartz, and feldspar near the Gauss/Matuyama boundary, paralleled by the onset of loess deposition in China, is interpreted as intensified atmospheric and oceanic circulation triggered by the development of major northern hemisphere glaciation near 2.5 Ma. The biogenic sediment composition of Site 798 and Site 799 sediments is characterized by high organic carbon contents; the organic matter is mainly a mixture of marine and terrigenous origin. Marine organic carbon enrichments are probably caused by increased preservation rate of organic carbon under anoxic deep water conditions and/or increased paleoproductivity.

One priority of our investigations is focussed on the characteristics and causes of the distinct cyclicity of the late Plio-/Pleistocene sediment composition at Site 798. Based on the isotope-, bio-, and magnetostratigraphy, these cyclic changes can probably be divided into two different genetic types.

The late Plio-/Pleistocene interval is characterized by short-term Milankovitch-type changes in both siliciclastic and biogenic sediment composition, probably reflecting glacial/interglacial, arid/humid climate cycles. Spectral analyses of logging data point to a dominant 41ky (tilt) cyclicity.

Superimposed to the climatic cycles, distinct, dark-light subcycles of 1,000 to 12,000 y with changes in biogenic and organogenic composition occur, indicating dramatic short-term paleoceanographic variations.

ANTHROPO-CHEMICAL POLLUTANTS: TRACERS FOR ARCTIC SEA ICE DYNAMICS?

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(Preliminary results from the E.S.A.R.E.1992, and AARI research program 1990)

Studies of anthropo-chemical pollutants in the Arctic region have been carried out in the framework of the GEOMAR E.S.A.R.E.´92 winter expedition to the Laptev Sea and during the AARI (Arctic and Antarctic Research Institute, St. Petersburg) Arctic research program in 1990. Compared to the Baltic Sea, one of the most polluted bodies of ocean waters, Arctic measurements show 1-2 magnitude higher concentrations of PCBs, HCH, DDT group (DDT, DDD, DDE) and PHC (petroleum hydrocarbons). Mean annual concentrations of pollutants in Siberian shelf areas amount to 1.0 ng/l PCBs, 1.66 ng/l HCH, 0.46 ng/l DDT and 15.5 yg/l PHC in sea water and 2.0 ng/l PCBs, 1.18 ng/l HCH, 0.41 ng/l DDT and 16.2 yg/l PHC in shelf ice (unpublished data, AARI 1990).

River discharge and waste waters of coastal industrial settlements are primary contributors of chemical pollutants into Arctic shelf water and sea-ice cover. Extensive yearly sea ice export from the Laptev Sea to the central Arctic Ocean thus could be responsible for a widespread distribution of chemical pollutants. Concentration and distribution patterns of anthropo-chemical pollutants are believed to record recent ice formation and drift processes in the entire eastern Arctic Ocean (Siberian shelf area, central Arctic Ocean, ablation areas). Re-identification of anthropo-chemical ice inclusions in the entire Arctic Ocean is believed to give references to Arctic sea-ice drift patterns, and will be a focal point of further investigations.

ENVIRONMENTAL CHANGE: THE NORTHERN NORTH ATLANTIC

(DFG Special Research Project 313, Kiel University, Germany)

The Norwegian-Greenland Sea and peripheral areas are of central importance for the renewal of deep oceanic waters and the circulation system of the world ocean. As such, the area is ideally suited for assessment of rate and scale of the variability of the Earth's climatic history. This applies especially to the effects of possible global warming or cooling.

The research emphasis of the SFB 313 is placed on the variability of living conditions and the environment in various spatial and temporal scales, as documented in recent planktonic and benthic associations and in Upper Quartenary marine sediments of the Northern Atlantic.

Alongside the studies in the Vøring Plateau region, areas of intensive deep-water renewal in the Greenland basin, the high accumulation area of the Barent Sea Fan and the biologically, highly active, ice border zone are included in the research program. Targeted are the recent processes of pelagic particle formation and vertical particle flow, recent planktonic associations and their restructuring during sedimentation, lateral sediment transport, benthic colonization patterns and benthic particle flow, and biochemical and geochemical turnover in and on the sediment. The knowledge gained shall also be applied to elucidate the process characteristics in the history of the marine environment as documented in the tempero-spatial development of planktonic associations and microbenthos, and in physical and chemical sediment characteristics through high temporal resolution analysis. Model simulations are to assess the reconstructed scenario, and may allow model prediction about future climatic development.

PALEOCEANOGRAPHIC AND PALEOCLIMATIC EVOLUTION IN THE WEDDELL SEA (ANTARCTICA) DURING THE MIDDLE EOCENE-LATE OLIGOCENE, FROM COARSE FRACTION AND CLAY MINERAL DATA

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C. Robert, and H. Chamley

Composition of the coarse sedimentary fraction (>63μm) and clay mineral associations have been studied in Antarctic sediments of middle Eocene to late Oligocene age drilled on Maud Rise (ODP Site 689) in order to detect environmental changes on the continent and in the ocean, and their probable relationships.

A continuous increase in surface water productivity beginning in the middle Eocene reached a maximum during the early Oligocene. Pedogenic smectite formed in warm climates with alternating humid and dry seasons largely dominates clay associations older than 41 Ma Detrital supply of illite (eroded from parent-rock and/or poorly weathered soils) started at about 41 Ma and increased at about 36 Ma in the earliest Oligocene, in relation to the cooling of Antarctica.

Middle Eocene deposits are enriched in clinoptilolite, which disappears at about 40 Ma, simultaneous to the oldest occurrence of biogenic opal: increased productivity of surface waters, and decreased sea-water temperatures probably prevented further development of clinoptilolite. This has been associated with a modification of clay associations (appearance of kaolinite) probably related to a change in the source areas of terrigenous particles at ODP Site 689.

The coarse sediment fraction and the clay mineral associations indicate that environmental and climatic conditions in east Antarctica deteriorated at about 41 and 36 Ma. The first step was associated with a dramatic change of oceanographic conditions (sea-temperature and productivity, stronger turnover and mixing in the ocean). The second step marked a maximum in oceanic productivity and cold conditions onshore. Climatic and oceanographic conditions later improved during the upper early and late Oligocene. Variations of surface water productivity during the Oligocene could possibly reflect cyclic changes of 400-500 kyr, sometimes associated with smectite/illite variations: there was a probable link between oceanographic and continental weathering conditions in Antarctic areas during the late Paleogene.

PALEOCEANOGRAPHIC CHANGES IN THE NORTHEASTERN PART OF THE NORWEGIAN SEA DURING THE PAST 50,000 YEARS

T. Dokken (Univ. of Tromsø, Norway) and M. Hald

One high-resolution core from the deeper part (2119 m) of the Spitsbergen/Barents Sea margin has been investigated by quantitative studies on both benthic and planktic foraminifera and oxygen and carbon isotope measurements on the planktic foraminifera *N. pachyderma* sin. The chronology is based on four AMS-datings and isotopic events.

Isotope stage 3 is characterized by a high foraminifera content dominated by left-coiled *N. pachyderma* and relatively stable isotope values which show cold water masses. A slow sedimentation rate (~2.8 cm/ka) with no significant input of coarse materials and positive $\delta^{13}C$-values, could imply open water masses with pure pelagic sedimentation.

The isotope stage boundary 3/2 is marked by a high number of foraminifera, increased amount of $CaCO_3$, an abrupt shift to more negative $\delta^{13}C$-values, heavy $\delta^{18}O$-values and a high input of *G. quinqueloba.* This event may be caused by a southward movement of the oceanic front between arctic and polar water masses at this time, which probably lead to an increased surface water productivity.

Stage 2, before 20 ka, is characterized with a high sedimentation rate (~21.2 cm/ka), negative $\delta^{13}C$- and heavy $\delta^{18}O$-values and a nearly absent foraminiferal content. This indicates glacial environment with a high input of ice-transported materials and ice coverage which prevent atmospheric gas exchange.

An abrupt paleoceanographic shift occurs at about 20 ka. This is reflected by a higher number of foraminifera, high $CaCO_3$ content and less negative $\delta^{13}C$-values, which imply that the northern part of the Norwegian Sea was not ice-covered before the onset of the last glacial maximum.

The onset of deglaciation is characterized with a melt-water spike (light $\delta^{18}O$ values) - here interpolated to 15 ka before present. The following period between 15 ka and 10 ka is nearly absent of foraminifera and, therefore, difficult to interpret.

The most distinguished episode in the Holocene is reflected by a high content of both *G. quinqueloba and G. bulloides* at 9 ka before present. This is most probably due to intrusion of Atlantic water masses.

NANNOPLANKTON PALEOGEOGRAPHY OF CENOZOIC ATLANTIC AND INDIAN OCEANS

O.B. Dmitrenko (P.P. Shirshov Institute of Oceanology, Moscow, Russia)

Deep-sea drilling by the "Glomar Challenger" (1969-1983) has produced a vast quantity of data on the biogeographical distribution of calcareous nannoplankton in all the Cenozoic epochs. This data has been used here as the basis for geographic zonation schemes of the Atlantic and the Indian Oceans for 25 Cenozoic time scales. The principal technique used in drawing the maps of biogeographical zonation was analysis of areal ranges of individual species and species-groups of nannoplankton. 12 to 50 maps of areal-ranges for individual species were compiled for each of the time intervals analyzed.

The boundaries of individual nannofossil areal-ranges were used as the basis for plotting the boundaries of biogeographic zones. For this, compilation of the schemes of the biogeographical zonation was preceded by paleoecological analysis of the species, and by determination of their temperature and geographical distribution. The analysis was carried out by comparing, stage by stage, areal-ranges of species and the changes in their abundance distribution from the recent to early Cenozoic time. By using this approach it was possible to make references to modern temperatures and to identify species and species-groups as climatic groups for recent and Pleistocene time intervals, and as paleoecological indicators of similar environments for thaphocoenoses far removed from the modern ones. It determined the groups which served as a basis for the biogeographical zones identified in Cenozoic. Changes in species diversity in time were also considered.

Subtropical and tropical zones existed in Cenozoic constantly. The moderate zones existed from 40 m.y., and subpolar, from Miocene. The narrowing of the tropical zone, the shiftings of the subtropical, temperate and subpolar zones toward the Equator and widening of the subpolar zones are evident. This process indicates a gradual cooling of climate at all latitudes in oceans during the Cenozoic.

DETECTION OF FINE-GRAINED OVERSPILL TURBIDITES USING OSTRACODS - SOME IMPORTANT IMPLICATIONS FOR CORE INTERPRETATION

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Overspill turbidites with highly distal characteristics are recognized from a range of depths on the continental slope of Australia's southern margin. These fine-grained turbidites are difficult to differentiate from hemipelagic sediments. The turbidites often lack a coarse base, structures are usually visible only in X-ray and compositional differences are subtle, reflecting the high proportion of slope sediment incorporated into the turbidites. Shelf-derived material in the sand fraction is size-sorted, and occurs mainly within the fine-sand fraction (150-63 μm). Components include small, but significant, percentages of biogenic spicules, mica and quartz, and high numbers of shallow-water ostracods.

Ostracods are microscopic crustaceans with a calcareous shell consisting of two valves. In the marine environment they are found in neritic to abyssal depths. The small size of the shallow-water ostracods present in the turbidites (typically less than 400 μm) and a lack of common large species indicate that sorting of the shelf sediment has occurred. The ostracod fauna derived from the slope provides evidence of the incorporation of sediment from a range of depths in the path of the turbidity current.

Because of the high content of slope sediment in the turbidites, foraminiferal biostratigraphy may not be obviously different from that expected. Any chemical record within the turbidite sediment, however, will reflect the composite nature of the sediment and will be further overprinted by the sorting processes of deposition. The likelihood of hiatuses further complicates interpretation of such sequences.

In the region studied, overspill turbidites are estimated to represent up to 25% of sediments deposited on the slope in the last 100,000 years. Evidence from cores elsewhere on the Australian margin suggests that such turbidites are widespread in their occurrence. Ostracods provide a powerful tool for the detection of overspill turbidites. Lack of detection of such turbidites has significant implications for the interpretation of $\delta^{18}O$ records in cores.

PLIOCENE CARBONATE SYSTEM ON THE QUEENSLAND PLATEAU: EVIDENCE FOR CARBONATE LOWSTAND SHEDDING

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Shedding of shallow carbonate material, towards the deep slopes and basin floors, is clearly tied to the position of the carbonate bank tops relative to the photic zone. In theory, bank-top shedding can be initiated either by flooding the bank top within the photic zone during a sea-level rise, following a period of exposure ("highstand shedding" scenario), or by re-entry of the bank top into the photic zone during a sea-level fall, following a period of drowning ("lowstand shedding" scenario). Past studies of Late Quaternary and Plio-Pleistocene periplatform sequences in the Bahamas, the Nicaragua Rise, and the Maldives, indicate that "highstand shedding" was the typical response of carbonate platforms to sea-level fluctuations. This is opposite to the "lowstand shedding" response which is typical for siliciclastic shelves.

Results of recent research on six Pliocene sequences, drilled along a transect of ODP Sites within different slope settings of the Queensland Plateau, reveal that high sedimentation rates, primarily related to the admixture of bank-derived material with the pelagic sediment in slope sequences, do not always correspond to the flooding of the platform top subsequent to its exposure. On the contrary, these periplatform sequences appear to have recorded the re-entry of the platform top into the photic zone during a sea-level fall, which followed an interval of high sea level during which the carbonate system was drowned. During the early Pliocene general sea level highstand (5.0 to 3.5 Ma), pelagic sediments were deposited on the slope of the Queensland Plateau, whereas during the late Pliocene general sea-level low stand (3.0 to 2.4 Ma), slope sedimentation was clearly periplatform in nature. Sediments deposited during the transition interval (early Late Pliocene, 3.5 to 3.0 Ma) between the Early Pliocene highstand and the Late Pliocene lowstand, recorded the fall of sea level by the synchronous occurrence of: 1) submarine hardgrounds in the shallowest sites; 2) the deposition of reworked material from the shallower part of the slope to the intermediate depth sites; and 3) the deposition of pelagic sediments in the deepest sites.

MORPHOLOGY AND SEDIMENTARY EVOLUTION OF THE DEEP FORE-REEF SLOPES OF THE COMORO ISLANDS IN COMPARISON WITH THE RED SEA AND THE CARIBBEAN

W. Dullo (GEOMAR, Kiel, Germany)

Grande Comore is the youngest island of the archipelago and in its submarine morphology it is strongly controlled by recent volcanism. The slopes, observed onshore, continue below the present-day sea level in the same inclination. Apart from its morphology that is still dominated volcanically, the shallow regions to 30 m are covered with scleractinies even on the youngest extrusions (15 years). Moheli already shows, especially on the western side, an independent morphology due to carbonate production and reef growth. This is particularly demonstrated by a most distinct terrace, currently at 120 m water depth. Its structure is probably related with the last glacial lowstand of sea level or shortly after its maximum, respectively. On the southern side, this terrace step can be followed across the east side to the north side. Characteristic rock walls are below this step, which can be found in the Red Sea, as well as in the Caribbean. The bathymetric range of these walls always begins below 100 m of present water depth and reaches to approximately 180 m. The ledge structures known from the Red Sea are found here on the rock walls, as well as on the steeply inclined (75° - 80°) deeper parts (down 250 m). Slopes with 30° to 45° tilt follow below showing thin sediment covers over cemented carbonates. Cipit boulders are found in some places.

The Island of Anjouan has an intermediate type of morphology because it possesses very thin fringing reefs and deeper carbonate fore-slopes; however, it is mainly dominated by volcanics below 130 m of present water depth.

Mayotte, as the oldest island of the ones investigated, has very well-developed fringing reefs and a circular barrier reef. On the SW side between the outer barrier and the coast there even exists an internal reef barrier. An independent fore-reef morphology has developed currently above 250 m of present water depth, owing to its age and a longer subsidence connected with that. Therefore, as on Moheli, there are very steep reef slopes on which the well-known ledge structures are located. First investigations indicate that the ledges are mainly built by *Halimeda* sand, whereas red algae and bryozoan occur as primary biogenic framework. According to our investigations in the Red Sea the primary framework here is also intensively corroded.

The volcanic basement was reached at a depth of 360 m on the west side below the rock walls. Here, the slopes that are covered by reef talus are differently inclined (20° - 45°). The top of the fans shows only a very thin sediment cover over cemented reef rud stones. This result perfectly matches the observations from the Caribbean and the Red Sea. According to these observations the steep walls and the cemented slope fans were formed during the last glacial, while formation of the ledges took place during rapid sea level rise. The last stage of present-day conditions is characterized by the accumulation of non-lithified talus at the base of the steep walls, as well as fine sediment trapping on top of the ledges.

RECONSTRUCTION OF VEGETATION ZONES IN NW AFRICA FROM MARINE PALYNOLOGICAL DATA: CONSEQUENCES FOR THE CO_2 ATMOSPHERIC BALANCE

L.M. Dupont (Institute of Palynology and Quaternary Sciences, Göttingen, Germany)

Expansion and contraction of vegetation zones, like desert or tropical forest have consequences for the total biomass. Biomass reduction releasing carbon dioxide will happen during dry periods when large areas change from savanna or forest into desert. Increase of biomass trapping atmospheric CO_2 will happen during humid periods when desert and open savanna is reclaimed by forest. An archive for vegetation change in NW Africa is found in deep-sea sediments of the NE Atlantic.

From palynological data of four marine cores between 38° and 29°N, a reconstruction for the last 250 ka is made of the extension of the Mediterranean forest, the northern Sahara, and the transitional steppes. For the last 700 ka, shifts of the Saharan-Sahelian boundary and the northern fringe of the tropical rain forest were reconstructed using data from 21°N and 9°N, respectively.

CALIBRATING ^{14}C-AGES WITH ^{230}Th AGES OF CORALS FROM NEW GUINEA AND VANUATU

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Development of mass spectrometric methods for measuring ^{230}Th (Edwards et al., 1987) and ^{234}U (Chen et al., 1986) has made it possible to calibrate the timescale beyond the range known from dendrochronology. A calibration from Barbados shows offsets between ^{14}C and ^{230}Th ages (Bard et al., 1990). Analytical improvements and analysis of new corals may allow us to refine and extend this calibration. The most important problems are: potential open ^{14}C or ^{230}Th systems.

We analyzed "infinite age" corals to check for contamination with young carbon. Results show that contamination can be significant but is removable by selective dissolution methods. We improved $^{234}U/^{238}U$ measurements to precisions of $\pm 1‰$ (2σ). This improves our ability to identify coral ^{230}Th ages that have been diagenetically shifted. Four Huon Peninsula, New Guinea and Barbados corals (<2,500 y B.P.) give initial $\delta^{34}U$ values that agree (mean and $2\sigma_{population} = 149.7 \pm 1.5$), establishing a precise value for modern sea water. Initial $\delta^{34}U$ values of 17 Huon corals (<13,500 y B.P.) are indistinguishable from this value, consistent with closed-system conditions.

We analyzed ^{14}C (± 80 y 2σ errors) and ^{230}Th (± 10 to 60 y errors) in 17 Huon samples and applied a reservoir correction of 407±52 y. For 5 corals (<9,000 y B.P., a period for which ^{14}C is well-calibrated), $\Delta^{14}C$ values are the same as those from dendrochronology, implying closed system conditions and a constant reservoir effect. For 6 corals (9,000 to 11,000 y B.P., a period for which ^{14}C is calibrated with a "floating" chronology), $\Delta\delta^{14}C$ values are again the same as those from dendrochronology, implying both calibrations are accurate. For 6 corals (11,000 to 13,500 y B.P.), results are consistent with other coral calibrations, within the larger errors of earlier work, but inconsistent with varve records that show lower $\Delta\delta^{14}C$ prior to 12,000 y B.P. Our most striking finding is the refinement of atmospheric $\Delta\delta^{14}C$ between 12,345±41 and 10,912±27 y B.P.: our data show a dramatic $\Delta\delta^{14}C$ fall of 176±21 per mil. Because of its rapidity and relationship to the Younger Dryas and times of maximum melting, some portion of the drop may well relate to climatic shift. We are continuing this study with analysis of sequences on Vanuatu, which extend beyond the Huon record.

U^{K}_{37} SECULAR GEOCHEMICAL RECORDS OF THE LAST 400,000 YEARS

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Molecular stratigraphy, utilizing abundances of biomarker organic compounds, is receiving increasing interest as a paleoclimatic tool. Many candidate molecules, notably straight-chain compounds, acyclic isoprenoids, sterols and pigments, are under study, but attention is focussing on the U^{K}_{37}index as a measure of past sea-surface temperatures (SST). This index is based on the relative abundances of two C_{37} alkenones biosynthesized by some Prymnesiophyte algae, for example, the ubiquitous coccolithophorid *Emiliania huxleyi*. These compounds partially survive mineralization in the water column and diagenesis in the bottom sediments. The small sample size needed for U^{K}_{37} analyses (minimum 0.1 g sediment) and automated analytical techniques facilitate high-resolution stratigraphy which can be integrated into multidisciplinary studies of Quaternary paleoclimatic records.

The approach is under continuous evaluation for calibration, including water column and benthic studies. Efforts are being made to place molecular parameters in context with other temperature proxies, such as those based on foraminiferal $\delta^{18}O$ values and species assemblages. Parallel studies of the same cores will help to establish precisely what each parameter is measuring. Our view is that the alkenone signal reflects euphotic zone temperatures at the time of maximum production of the Prymnesiophytes. Typically, in the North Atlantic, the spring bloom period occurs in April at about 40° N, progressing to June-July at 60° N. Our recent water column studies (UK BOFS programme) show that temperature estimates for these colder waters (<15°C) is better evaluated by a new molecular proxy, the Integrated Production Temperature (IPT), which is based upon the abundances of both the alkenones and the alkyl alkenoates. While U^{K}_{37} appears to broadly reflect temperature changes at warm water sites, IPT may be applicable over a wider ranges of water temperature, algal species and strains.

U^{K}_{37} records presently available refer to stratigraphy at resolutions from annual to several thousand years, and time spans from a few hundred years to several hundred thousand years. Areas studied include sites in different oceans (though mostly upwelling), latitudinal extremes from equatorial to high latitudes (72°N), and water temperatures ranging from 6-25°C.

THE EOCENE/OLIGOCENE IN THE SOUTHERN OCEAN

W.U. Ehrmann (Alfred Wegener Institute, Bremerhaven, Germany) and A. Mackensen

Stable isotopes, carbonate content, opal content, grain-size distributions, and clay mineral assemblages of middle Eocene to late Oligocene sediments from 6 ODP sites on Maud Rise and Kerguelen Plateau were investigated in order to study depositional environment and paleoclimate.

Both benthic and planktonic oxygen isotopes document a cooling trend beginning around 49.5 Ma. Some isolated terrigenous sand grains of probably ice-rafted origin and the clay mineral assemblages point to the existence of a limited East Antarctic ice cap with some glaciers reaching sea level as early as ca. 45.5 Ma. Between 45 and 40 Ma, average paleotemperatures of the deep water masses were between 5 and 7°C; near-surface water masses ranged between 6 and 10°C. Between 40 and 36 Ma, average temperatures further decreased to 4-5°C in the deep and intermediate water masses and to 5-8°C near the surface. The growth of the inland ice resulted in enhanced physical weathering and in increased contents of detrital chlorite and kaolinite from about 40 Ma.

The onset of continental East Antarctic glaciation is recorded in earliest Oligocene sediments. The clay mineralogy changed between 36.3 and 35.5 Ma from smectite-dominated assemblages to illite- and chlorite-dominated assemblages, the latter being indicative of physical weathering under cooler climates. Large quantities of ice-rafted gravel and sand accumulated on the Kerguelen Plateau at 36.0-35.8 Ma. At the same time, an increase in opal content occurred as well as a decrease in carbonate. At 35.9 Ma planktonic and benthic foraminifera show an abrupt increase in oxygen isotope values ranging between 1.0 and 1.3‰, and between 0.9 and 1.4‰, respectively.

We favor a hypothesis that explains most of the isotopic shift with a build-up of a continental East Antarctic ice sheet. Consequently, relatively warm Oligocene Antarctic surface water temperatures probably are explained by a temperate, wet-based nature of the ice sheet, which covered most of East Antarctica. This would also aid in the fast build-up of an ice sheet by enhancing the moisture transport onto the continent. The temperate nature of the ice sheet would also allow the observed occurrence of *Nothofagus* and would explain the lack of long-distance transport of debris by icebergs.

HOLOCENE SEA LEVEL DETERMINATION RELATIVE TO THE AUSTRALIAN CONTINENT - U/TH (TIMS) AND ^{14}C (AMS) DATING OF CORAL CORES FROM THE ABROLHOS ISLANDS

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We present U -Th (TIMS) and ^{14}C (AMS) measurements of two coral cores from the Easter group of the Houtman Abrolhos islands between 28° and 29°S on the Western continental margin of Australia. The U/Th measurements on the Morley core (MC) from Morley Island covers a depth interval from 0.2 m above present sea level to 24.4 m below present sea level and consists of eleven samples. The ages vary between 6320±50 a at 0.2 m above sea level and 9809±95 a at 24.4 m below sea level (all errors are two standard deviations).

The mean growth rate is 7.1±0.9 m/ka. However, the growth rate is not uniform but shows three different sections with marked changes of slope corresponding to 3.2 m/ka (section I), 25 m/ka (section II) and 8.5 m/ka (section III). The ^{14}C data of selected Morley core corals show that the ^{14}C ages are about 1000 a younger than their corresponding U/Th ages in accordance with previous results (Bard et al., 1990). However, there is general agreement between the related dendrochronological ages and the U/Th ages. We consider these U/Th ages to be calendar years. The main purpose of our ^{14}C measurements is a precise comparison to other coral cores where no U/Th measurements are available.

The U/Th measurements of the Suomi core (SC) from Suomi island covers from 0.05 m to 14.2 m below sea level and consists of 4 samples. The ages vary between 4671±40 a at 0.05 m below sea level and 7102±82 a at 14.2 m below sea level with a mean growth rate of 5.8±0.2 m/ka.

The growth history of both cores is explained by a simple model in which the growth rates of the Morley core can be interpreted as reflecting local rates of sea level rise. The Suomi core is interpreted to reflect lateral growth during the past 6000 a when local sea level did not change markedly. It is argued that the Abrolhos Islands are free of the influence of any significant tectonic movement or of any substantial hydroisostatic adjustment. Our results indicate that sea level relative to the Western margin of the Australian continent was about 24 m lower than present at about 9800 a B.P. (^{14}C: 8500 a B.P.). Sea level rose and reached a highstand, slightly higher than the present position, at about 6300 a B.P. (^{14}C: 5500 a B.P.). This highstand declined but was still higher than present at 4600 a B.P. This is in agreement with previous observations along the Australian coastal margin and with observations from the Huon Peninsula (Papua-New Guinea).

Our results are very similar to theoretical numerical models considering water loading and involving isostatic compensation and mantle flow for a viscous upper mantle (Peltier, 1987; Lambeck and Nakada, 1990). In contrast, coral cores from Barbados (Fairbanks, 1989) show that corals with a ^{14}C age of 5500 a B.P. are some 10 m b.p.s.l.. We interpret the difference between the Barbados core and the Morley core as additional "flooding" of Barbados by water redistribution due to changes of the Earth's geoid but not reflecting global sea level rise or major addition of meltwaters over the past 6000 a. The difference in the geoid at Barbados between 6000 a B.P. and the present will require a refinement in the geophysical models. Precise ^{230}Th (TIMS) measurements on continental coasts will be required to provide an adequate data base for modelling deformation, flow of mantle material and sea level height.

TRACE METALS INCORPORATION IN FORAMINIFERAL CALCITE AS A FUNCTION OF WATER COLUMN CHEMISTRY: MODEL RESULTS AND EXAMPLES FROM Sr/Ca AND REE/Ca DATA

H. Elderfield (Dept. of Earth Sciences, Univ. of Cambridge, UK), C.J. Bertram, and J. Erez

There is much interest in the development of new chemical tracers of pCO_2, nutrients and oxygen in the palaeoceanographic record. One difficulty experienced in such developments has been an understanding of factors controlling cation incorporation in biogenic calcite. Sr/Ca ratios in planktic and benthic foraminifera show significant variability within oceans and between interglacial and glacial time that cannot be attributed to ocean chemistry. In contrast, abundance patterns of rare earth elements (REEs) in planktic and benthic foraminifera are consistent with ocean chemistry.

A fundamental problem is that D_{Me} values for biogenic marine calcite are most likely kinetically controlled and are difficult to predict from inorganic values based upon equilibrium considerations. A conceptional model for biogenic calcification is presented, based upon the "internal pool" concept of Kuile and Erez (1987). The model considers two end members: shells that incorporate metals with the inorganic value for D_{Me} and those with D_{Me}=1 with observational data described by Rayleigh fractionation between these end members. The

possibility of using the model to correct for variations in D_{Me} caused by calcification rates effects is explored using Cd/Ca and Sr/Ca.

ALKENONE SEA-SURFACE TEMPERATURES AND PRODUCTIVITY AT ODP SITE 846 (EASTERN EQUATORIAL PACIFIC) IN THE LATE QUATERNARY

K.-C. Emeis (Geologisch-Paläontologisches Institut, Universität Kiel, Germany), D. -Bull, and H. Doose

Site 846 of Leg 138 is located within the region of interactions between the South Equatorial (warm and nutrient poor) and the Peru (cold and nutrient-rich) current systems. The area is thus characterized by considerable spatial gradients in sea-surface temperatures (SST) and biological productivity. Location of Site 846 relative to the oceanic front and to zones of high biological productivity in the late Cenozoic was influenced by the displacement of current systems (as a function of wind systems and wind intensity) and by movement of the Nazca Plate towards the South American continent.

We measured the alkenone unsaturation ratio of lipid extracts, carbonate and organic carbon concentrations to elucidate oceanic current regime and productivity history of a sample set from Site 846 (first in a N-S transect of sites). The samples cover the last 700 k.y. with an average resolution of < 10 k.y. Applying a preliminary age model, we discern considerable temporal and spatial variability of SST (ranging from 20°C to 28°C) and of accumulation rates of carbonate (0.2 to 3 g/cm^2-k.y.) and organic carbon (5 to 30 mg OC/cm^2-k.y.). SSTs consistently showminimal values during glacial stages for the last 700 ka. Pronounced maxima in the accumulation rates of organic carbon and $CaCO_3$ around 400 ka, 280 ka, and since isotope stage 3 coincided with colder SST. Since 280 ka, a period of minimal SST (20°C) and maximal biogenic accumulation, the sea-surface temperature record at Site 846 fluctuated in concert with global trends in ice volume (as expressed by the SPECMAP isotope composite of planktonic foraminifers) and global temperature.

DEGLACIATION OF THE BALTIC SEA: NEW PALEOCEANOGRAPHIC MAPS AND PALEOCEANOGRAPHY

E.M. Emelyanov (P.P. Shirshov Institute of Oceanology, Atlantic Dept., Academy of Sciences, Kaliningrad, Russia)

Vast geological and geophysical investigations were performed in the Baltic Sea during the last 25 years (5,000 geological stations, 50,000 km of CSP). Six dives aboard the submersible "Mir" were carried out in the Northern Baltic and the Gotland Deep. All the data were analyzed in the Atlantic Department of the Institute of Oceanology (Kaliningrad) and other institutions of Russia.

Long cores were stratigraphically investigated; about 200 age determinations (^{14}C) were made. Many cores were analyzed by X-ray and chemical analysis (25 elements). Individual cores were studied together with Polish, German, Danish, and Swedish scientists.

On the basis of these data many paleoceanographical profiles and maps were compiled: a) a map of Pre-Quaternary basement (scale 0.5 mln); b) a map of Quaternary deposits (scale 0.5 mln); and c) paleolithological maps (for stages of 10.5, 9.5, and 8.5 thousand years) (scales 1.25 and 0.5 mln.).

Additional hypsometrical maps for stages 10.5, 10.0, 9.5, 9.0, 8.5, 8.0, 7.5, and 7.0 thousand years were compiled by E. Romanova (1991).

On the grounds of these data, the problem of the Baltic Sea deglaciation is being discussed.

UNCONSOLIDATED BOTTOM SEDIMENTS OF THE MEDITERRANEAN SEA AND PALEOCEANOGRAPHY

E.M. Emelyanov (P.P. Shirshov Institute of Oceanology, Atlantic Dept., Academy of Sciences, Kaliningrad, Russia) and K.M. Shimkus

A new unconsolidated bottom sediment map (scale 1:1,000,000, 10 sheets) was compiled by Emelyanov and Shimkus according to the UNESCO Intergovernmental Oceanographic Commission Program. Representatives from Turkey, Israel, Egypt, Spain, France, Italy and Greece contributed their data. Folk's triangle (1974) was used for classification. A special legend recommended by UNESCO WG was employed. Grain-size distribution is shown by shading; genetic types of sediments by color.

Hundreds of miles of CSP profiles, dredging data and underwater TV records were used. The tops of the mountains of the Tyrrhenian Sea (Verchelli, Vavilov, Palinuro, Marsili, Baroni Crest) were investigated with the submersible "Argus." For hard rock drilling we employed a special drilling apparatus. We obtained and studied dozens of cores of basalts, breccias and limestones.

Ferrigenous hydrothermal deposits (Fe up to 32.4%, Mn up to 9.19%, P up to 0.62%, Ni up to 0.013%, Co up to 0.008%, Li up to 0.015%, V up to 0.023%) were discovered on the top of Marsili. Sediments of the Bannock anoxic basin were studied. They are enriched in $CaCO_3$ (50-60%) and Sr, Cu, Li, and Ni. The sediments contain crystals of gypsum, stroncianite and pyrite. Turbidites are enriched in pelicles.

In addition, we investigated the influence of peridotites and basalts on mineralogical and chemical composition of sediments (Cyprus province, Nile, volcanoes). All data are discussed from a paleoceanographical point of view.

THE PALEOEQUATORIAL UPWELLING BELT IN THE MESOZOIC PACIFIC OCEAN: RESULTS OF ODP LEG 129

E. Erba (Dipartimento di Scienze della Terra, Università di Milano, Italy), Y. Lancelot, R.L. Larson, and M.Steiner

Sediments recovered during ODP Leg 129 in the western tropical Pacific record the history of the oldest portion of the Pacific plate. Qualitative and quantitative data of calcareous nannofossil and radiolarian assemblages, paleolatitude computed from sediment inclination, skewness of magnetic anomalies, paleomagnetism of seamounts, and plate motion based on fixed hotspots were combined to derive the tectonic history and motion of the Pacific plate in the Mesozoic.

During the Middle Jurassic, the Pacific plate originated at equatorial southern paleolatitude and drifted south through the Late Jurassic and Early Cretaceous. A reversal from southward to northward motion occurred probably near the Barremian/Aptian boundary; northward drift continued through the rest of the Cretaceous and Cenozoic.

Changes in nannofossil assemblages and radiolarian abundances were combined with paleolatitudes to trace the response of planktonic communities to plate motions toward the paleoequator and the transit at the paleo-upwelling belt.

Aptian to Cenomanian calcareous nannofloras record changes in composition, with sharp increases in abundance of the high-fertility indicator *Biscutum constans* and *Zygodiscus erectus* when sites were approaching the paleoequator. Paleoecology indices suggest that Site 801 reached the southern edge of the paleoequatorial high-productivity zone during the late Albian at 15°-20°S paleolatitude, as indicated by an interpolation between the oldest seamount pole and the youngest skewness pole. Site 801 then crossed into the core of the upwelling belt during the late Cenomanian at 15°-10°S paleolatitude, as indicated by the oldest seamount pole data. The comparison of several Mesozoic Pacific sites suggest that the sedimentation depended mainly on paleolatitudes and was strongly controlled by an equatorial silica bulge.

Our data suggest that during the Cretaceous the geography of the paleoequatorial high-productivity zone was different than it is today. Either the entire productivity belt was shifted south relative to the paleoequator, or was more extensive then at present.

IMPRINTS OF LATE HOLOCENE NW EUROPEAN ENVIRONMENTAL CHANGES ON THE RADIONUCLIDE AND STABLE ISOTOPE RECORD OF THE SKAGERRAK SEDIMENTS

H. Erlenkeuser (Inst. Nucl. Physics, C14-Lab., Kiel, Germany)

In the last millennium major climatic and environmental changes have occurred in NW Europe and have modulated the oceanographic and depositional conditions in the North Sea area. We have attempted to identify these changes in the radionuclide and stable isotope records of sediment cores from the Skagerrak, which as a depository of North Sea fines and due to its hydrographically sensitive position between the Norwegian Sea and the Baltic, should provide an interesting archive of these changes.

^{14}C of the total organic fraction (TOC) proves strongly affected by older allochthonous organic carbon. The ^{14}C-results indicate a systematic decrease of the allochthonous input between about 800 A.D. and 1100 to 1300 A.D. and again a reinforcement since then, with a particular pulse of older carbon input about 1500 A.D. Covariant changes of the $\delta^{13}C$ TOC suggest that parts of the allochthonous organic matter originate from terrestrial sources and hence may relate to the coastal land areas and their deposits, such as Holocene peat bogs, lost to the North Sea.

The oxygen isotope ratio of benthic foraminifera shows a more or less-pronounced minimum of the isotopic temperature in post-medieval times. In the fast accumulating, highly resolved deposits from the SE Skagerrak even finer details of the climate history appear to be approached (in cooperation with C. Hass, Geomar). Benthic $\delta^{13}C$ values, systematically decreasing after 1900 A.D., likely respond to anthropogenic effects such as the release of nutrients to the marine environment or of CO_2 from fossil fuels.

Problems still exist with the dating of the sedimentary records. ^{14}C is affected to a variable extent by allochthonous matter of different age and for the last millennium suffers from secular variations. Dating by ^{226}Ra-supported ^{210}Pb could provide an attractive method for the range of the last 1 to 2,000 years, although the role of a varying geochemical and depositional environment still has to be investigated. Dating the last 100 years of the sedimentary record via excess ^{210}Pb appears to provide comparatively reliable results.

Cooperation (samples, discussion) with C. Hass, P. Jørgensen, J. Thiede, and F. Werner is acknowledged.

OXYGEN ISOTOPE STAGE 5 IN THE NORWEGIAN-GREENLAND-SEA: OCEANOGRAPHIC AND ECOLOGICAL ASPECTS FROM ISOTOPIC AND BENTHIC FORAMINIFERAL EVIDENCE

H. Erlenkeuser (Special Research Project 313, Kiel, Germany) and F. Haake

Oxygen isotope stage 5 (OIS 5), with particular emphasis on substage 5a, was studied with high (up to 1 cm) resolution through isotopes of planktic and benthic foraminifera, both epi- and endobenthic taxa, benthic foraminiferal abundancies, shell weights, and total organic carbon isotopes in cores from the Norwegian/Greenland Sea (NGS).

The isotopic records reveal a fine structure which is very consistent in the different cores and partly reflects global climatic events superimposed on the well-known broader isotopic pattern. Isotope differences between *C. wuellerstorfi* and *O. umbonatus* suggest that the $\delta^{18}O$ signal of *C. wuellerstorfi* from NGS sediment samples could be biased toward deep-convected light $\delta^{18}O$ of brackwater brines, the effect depending on core location, water depth and paleoceanographic context.

The benthic foraminifer *P. bulloides* indicates phases of North Atlantic water being advected to the NGS at the surface and readily mixed to the bottom. In this sense formation of deep-waters was most direct and thorough in the NGS including the Fram Strait in late OIS 5a. Interestingly, and in contrast to OIS 5a, there is no evidence in our cores that during OIS 5c North Atlantic waters reached the NGS as surface waters, except perhaps in the Iceland Sea.

As to OIS 5e, ecological conditions appear to improve according to our eastern cores only under the cooling climate in the trailing phase of this warm stage. If deep water formation was generally reduced in the NGS under peak interglacial conditions, greenhouse warming might become accentuated in the future as the uptake of anthropogenic CO_2 by the NGS waters would be substantially reduced.

A MULTIDISCIPLINARY APPROACH FOR THE USE OF PHYTOPLANKTON AS INDICATORS OF PALEOPRODUCTIVITY: EXAMPLE FROM UPPER CRETACEOUS ORGANIC-RICH CARBONATES IN ISRAEL

Y. Eshet (Geological Survey, Jerusalem, Israel), A. Almogi-Labin, and A. Bein

Dinoflagellates, nannoplankton and diatoms are the major primary producers in the ocean, whereas foraminifera are among the first-order consumers. These organisms represent the lower trophic levels and constitute most of the biomass in the oceans. Being strongly influenced by the environment, they are good ecological indicators.

Planktonic foraminifera from Upper Cretaceous organic-rich carbonate ("oil shale") sequences in Israel have been used to estimate levels of productivity. In this study, fossil phytoplankton (calcareous nannofossils and organic-walled dinoflagellates) are examined in the same samples and sequences, in order to establish an independent paleoproductivity scale. Dinocysts, unlike foraminifera

and nannofossils, can be recovered from cherts and, thus, can complete the paleoecological picture in cherty intervals.

Microfossil analysis of Upper Cretaceous organic-rich carbonates in both northern and southern Israel show two major dinocyst groups (with two possible subgroups): assemblages dominated by peridinioid (P) cysts, and assemblages dominated by gonyaulacoid (G) cysts. In present-day oceanic plankton, most living G-cysts belong to autotrophic (photosynthetic) dinoflagellates, while most P-cysts represent heterotrophic dinoflagellates, feeding mainly on diatoms. P-cysts are dominant in recent and subrecent upwelling areas, whereas in gyre centers or in other areas of low productivity, most cysts are of the G-type. The P/G ratio is considered to be indicative of primary productivity: high P/G values represent strong upwelling and nutrient-rich, low-oxygen water, whereas low values represent lower productivity and weaker upwelling. The results show that high P/G ratios correlate well with intervals for which both foraminifera and geochemical data suggest high productivity in response to upwelling. Low P/G ratios are found in intervals of lower productivity, possibly in response to less intensive upwelling.

HIGH-RESOLUTION $^{230}Th/^{234}U$-DATED SEA -LEVEL RECORD FROM BARBADOS SPANNING THE PAST 30,000 YEARS

R.G. Fairbanks (Lamont-Doherty Geological Observatory, Palisades, NY, USA), J. Rubenstone, Y. Lao, T. Guilderson, and A. Zindler

The original radiocarbon-dated, sea-level curve for Barbados has been redated using the $^{230}Th/^{234}U$ method. More than 50 dates have been measured, providing a more accurate and detailed sea-level curve. Melt water pulses (MWP) IA and IB were more rapid than previously estimated based on the original radiocarbon measurements. The $^{230}Th/^{234}U$ dating yield rates of sea-level change which were nearly equal for MWP IA and IB and ranged from 45 to 50mm per year. Peak discharge for MWP IA and IB occurred at 14,000 and 11,300 yrs. B.P., respectively. These pulses dramatically mark the Bolling/Allerød and Younger Dryas/Preboreal climate transitions. In addition, three smaller pulses are resolved by the $^{230}Th/^{234}U$-dated sea-level curve. In the frequency domain, ice volume changes may lag climate forcing; however, during the deglacial period, the rate of change of ice volume (or its sea level equivalent) responded instantaneously to climate warming.

The radiocarbon time scale is calibrated back to ~12,000 yrs. B.P. using tree rings and is corroborated by the $^{230}Th/^{234}U$ method over the same time interval. The Barbados $^{230}Th/^{234}U$-radiocarbon calibration for the interval 12,000 to 22,000 yrs. B.P. is crudely approximated by the following equation:

$$^{14}C\ (\text{Libby kyrs.}) = 0.7580 \times (^{230}Th/^{234}U\ \text{kyrs.}) + 1.187$$

$$R_2 = 0.984;\ n = 17$$

Pristine aragonitic corals suitable for ^{14}C and $^{230}Th/^{234}U$ dating are available in the Barbados offshore cores spanning nearly the entire radiocarbon time scale. Radiocarbon calibration on century to decade resolution is in progress.

LINKS BETWEEN NANNOFOSSIL PRESERVATION AND CARBONATE SEDIMENTATION IN NEOGENE SEDIMENTS FROM THE EASTERN EQUATORIAL PACIFIC (ODP LEG 138)

J.W. Farrell (Dept. of Geological Sciences, Brown Univ., Providence, RI, USA), I. Raffi, J.-A. Flores, and K.C. Emeis

We examine the Neogene history of carbonate preservation and flux in two latitudinal transects of drill sites from the Eastern Equatorial Pacific by combining calcareous nannofossil preservation data with measurements of calcium carbonate concentration (weight percent of dry bulk sediment) and mass flux ($g/cm^2/kyr$). During Ocean Drilling Program Leg 138, nearly 1,700 nannofossil smear slides from eleven drill sites were rapidly and qualitatively evaluated for not only biostratigraphic and taphonomic data, but also for data concerning nannofossil preservation state, abundance, etching and overgrowths. We also measured $\%CaCO_3$ in over 2,600 samples for the eleven sites. The $\%CaCO_3$ data are converted into $CaCO_3$ flux estimates by using shipboard measurements of dry bulk density and sedimentation rates derived from age models published in the *Proc. ODP, Init. Repts., 138*. To meaningfully examine the results, the nannofossil and $CaCO_3$ data from the various holes at each site are converted from the shipboard depth-in-hole scale ("meters below sea floor"), to a composite depth scale ("meters composite depth"). The composite depth scale for each site is constructed from the stratigraphic information gathered from the two or more holes drilled at each site. This scale accounts for, and by-passes, missing sediment intervals between cores and intervals disturbed by the coring process. The nannofossil preservation data help us interpret the $\%CaCO_3$ data.

Sedimentary intervals characterized by low $\%CaCO_3$ and poor nannofossil preservation are interpreted as times of enhanced dissolution. Intervals with low $\%CaCO_3$, but correspondingly good preservation, suggest dilution by terrigenous sediments in some instances and increases in biogenic opal in others. Additional information from shore-based studies allows us to differentiate between these two choices. Certain events in the sedimentary records, such as an extreme dissolution event at 9 Ma, are common to all sites, while other events are less regional in extent. A chronology of $CaCO_3$ sedimentation and nannofossil preservation will be presented from each site, and will be interpreted in a paleoceanographic and paleoclimatic framework.

LATE PLEISTOCENE STABLE ISOTOPE RECORDS FROM SURFACE OCEAN AND THERMOCLINE DWELLING PLANKTIC FORAMINIFERA: ODP SITE 847, EASTERN EQUATORIAL PACIFIC

J.W. Farrell (Dept. of Geological Sciences, Brown Univ., Providence, RI, USA), D. Murray, and S. Clemens

Detailed and continuous records of oxygen and carbon isotopes from *Globigerinoides sacculifer*, a shallow-dwelling planktonic foraminiferal species, and *Neogloboquadrina dutertrei*, a deep-dweller, are presented for the 0 to 1 Ma interval from Ocean Drilling Program Site 847, drilled in the eastern equatorial Pacific (0.12°N, 95.19°E, 3,335 m) during Leg 138. These records are from a composite depth sedimentary section constructed from multiple holes drilled at offset depths at the site. The records have an average sample spacing of 15 cm which approximates a time interval of 4,400 years.

The oxygen isotope data provide a chronology for the site and a means for detailed temporal correlation to other Leg 138 sites. The chronology allows us to calculate the rates of biogenic sediment fluxes (carbonate and opal) and to evaluate the temporal relationships between the fluxes (see accompanying poster by Murray et al.). These data also provide a climatic record of global ice volume fluctuations.

Gradients in the isotope records between the surface and thermocline dwelling planktic foraminifera are examined in light of variations in faunal abundance, dissolution intensity, nutrient gradients, temperature, and upwelling.

DIATOM SPECIES DISTRIBUTION PATTERNS IN SURFACE SEDIMENTS OF THE SW-PACIFIC

J. Fenner (Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, Germany)

More than 100 samples of surface sediments east of New Zealand between 35°S and 55°S have been analyzed quantitatively for diatom species. Four assemblages can be differentiated: 1) the low nutrient-open ocean-subtropical assemblage, 2) the upwelling-subtropical assemblage along the northern Chatham Rise, 3) the mixed temperate-subpolar assemblage of Bounty Trough, and 4) the fully subpolar assemblage south and east of Campbell Plateau.

The oceanic front of the "Subtropical Convergence" along Chatham Rise can be defined from the distributional pattern of planktonic diatoms as the northern link of occurrence of antarctic-subantarctic species like *Nitzschia kerguelensis* and *Thalassiosira lentiginosa.*

PHOSPHORUS ACCUMULATION RATES IN THE EASTERN EQUATORIAL PACIFIC FROM MIOCENE TO PRESENT: RESULTS FROM SITES 844, 846, AND 851, ODP LEG 138

G. Filippelli (Earth Sciences Dept. and Institute of Marine Sciences, Univ. of California, Santa Cruz, USA) and M. Delaney

Phosphorus (P) is a limiting element for productivity and carbon burial on long time scales; therefore, determining the oceanic record of P availability is important for elucidating long-term controls on oceanic productivity. Given the persistence of productivity in the eastern equatorial Pacific, we examined patterns of P accumulation in sediments from ODP Leg 138. With a typical sampling interval of tens to hundreds of ky's, we sampled from basement contact to the Late Neogene at three sites: two eastern transect sites (844 at 8°N, from 18-2 Ma, and 846 at 3°S, from 17-5 Ma) and one western transect site (851 at 3°N, from 11-5 Ma).

We used a chemical sequential extraction technique to distinguish P associated with five different sedimentary components: authigenic/biogenic material, iron-rich oxides/oxyhydroxides, organic matter, detritus, and an adsorbed fraction (Ruttenberg, 1990). P in these sediments is primarily associated with authigenic/biogenic components (typically >80% of total), with iron oxyhydroxides and organic matter of secondary importance (typically 5-10% each of total). Adsorbed and detrital components are minor P sinks (typically <1% each of total). Using sample wt% P with depth-age models for each site, we calculated P mass accumulation rates, reported here as the total of all sedimentary components (P-MAR in μmol $P \cdot cm^{-2} \cdot ky^{-1}$).

P-MAR for the eastern transect Sites 844 and 846 display a similar range, and both decrease slightly from 17 to 10 Ma, varying between about 20 and 40. At 10 Ma, both sites record a dramatic drop in P-MAR to less than 10, and remain constant until about 7 Ma. After 7 Ma, P-MAR at Site 844 remain low at about 10, while P-MAR at the more southerly Site 846 increase sharply to 50. Although consistently higher, P-MAR at western transect Site 851 display similar trends to the eastern and southerly Site 846, sharply decreasing at about 10 Ma from 50 to 10, followed by an increase to 50 after 7 Ma. We will extend the P-MAR record for Site 851 to the present and discuss P-MAR results for each of the five sedimentary components.

SEASONAL PARTICLE FLUX IN SOME HIGH PRODUCTION AREAS OF THE EASTERN ATLANTIC

G. Fischer (Universität Bremen, Germany) and G. Wefer

Time-series sediment traps were deployed off Mauretania (Cape Blanc), in the northern and southern Guinea Basin and off Namibia (Walvis Ridge). The highest total fluxes (64.3 and 60.8 g $m^{-2}yr^{-1}$), as well as carbonate (27.6 and 33.9 g $m^{-2}yr^{-1}$) and biogenic opal fluxes (5.2 and 8.5 g $m^{-2}yr^{-1}$) were recorded at the two coastal sites, off Mauretania and off Namibia, respectively. Intermediate annual rates were measured north, and low rates south of the equator.

The most distinct flux maxima north of the equator were during July-August, both at the Cape Blanc and the northern Guinea Basin sites, and corresponded to strong NE trade winds and intensive upwelling of cold and nutrient-rich water. At the Cape Blanc site, lithogenic fluxes correlate with biogenic fluxes. A second prominent flux maximum was observed in boreal spring at both equatorial sites, corresponding to the southernmost penetration of the ITCZ. This period was also characterized by a relatively high lithogenic contribution. South of the equator, sedimentation decreased rapidly to almost zero after May when the ITCZ migrated northwards.

Seasonality of fluxes was most clearly expressed at the Walvis Ridge site where distinct maxima occurred in June-July and October-November. During the latter period, wind-driven upwelling is strongest and the Namibia upwelling cell shows the greatest extension to the west. Contribution of lithogenic material to total fluxes was minimal at this site.

MILANKOVITCH IN THE GREENHOUSE

A.G. Fischer (Dept. of Geological Sciences, Univ. of Southern California, L A, USA) and D.J. Bottjer

Hemipelagic Cretaceous and Eocene chalk-marl strata show a curious linkage of precessional (20,000 ka) cycles (bedding couplets) that combines a carbonate (coccolith) productivity cycle, generated in the mixed layer, with an aeration cycle on pycnoclinal bottoms. In the carbonate-rich phase the bottoms were aerated, whereas in carbonate-poor phases an oxygen deficit is expressed in (1) darker color and (2) a spectrum of ichnofabrics extending from unburrowed black shales through *Chondrites* clays and marls into chalks churned by *Planolites* and *Thalassinoides.* The carbonate productivity is modulated by the 100 ka eccentricity cycle. We suggest that the aerated carbonate phase corresponds to the aphelial summer phase of the precessional cycle, enhanced by low eccentricity, and thus correlates with the ice-growth phase of the Pleistocene, whereas an oxygen deficit in the pycnocline developed in the perihelial summer phase. Red intervals in the Umbrian sequence of Italy are aerated throughout and represent deep times when bottoms lay in the oxygenated waters below the oxygen minimum zone. We suggest that in the greenhouse state the pycnocline is very susceptible to oxygen deficits, due in part to accelerated kinetics. Widespread development of an oxygen-depleted pycnocline poses problems for bathyal nektoplanktonic life. Were major elements of Cretaceous pelagic and benthic faunas adapted to dysaerobic life? Did others find means of penetrating anaerobic barriers? A reconsideration of Cretaceous faunas is called for. Will return of a greenhouse bring pycnoclinal anoxia?

CALCAREOUS NANNOFOSSIL HIGH RESOLUTION QUANTITATIVE ANALYSES IN THE PLIOCENE OF ODP SITES 849 AND 852 (LEG 138, EASTERN EQUATORIAL PACIFIC)

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Quantitative analyses of calcareous nannofossils were carried out on high resolution sampling of Upper Pliocene sediments from Holes 849D and 852D (ODP Leg 138; Eastern Equatorial Pacific, western transect). Depending on the sedimentation rates, which were calculated on board from biochronological and magnetotratigraphic data, the sampling interval was from 10 to 20 cm and the temporal resolution around 8500 years

Slides were processed following a standard technique. Starting from a weight of dry sediment, the absolute variation of the total nannofossil content or single selected species or morphotypes was estimated. A total of ≈500 nannoliths larger than 3 μm was counted (medium and large-sized Nannoliths: MLN). In the same number of visual fields, nannoliths smaller than 3 μm (Very Small Nannoliths: VSN) were also considered. Quantitative results are presented as nannoliths per surface (visual fields , mm^2).

As regards the VSN, 3 minima in abundance are observed at ca. 3.0, 2.5 and 1.8 Ma, and peaks of maximum abundance at ca. 3.2, 2.3 and 2.0 Ma. The MLN and VSN show an inverse pattern. The Asteroliths are moderately abundant and in general terms follow the VSN distribution. In the Upper Pliocene *Coccolithus pelagicus* shows a peak in abundance at around 2.4 Ma and is absent up to 3.0 Ma.

Fluctuations in the abundance of the groups considered are related to paleoceanographic and paleoclimatic changes (i.e., onset of Northern Hemisphere Glaciation).

HIGH-RESOLUTION STABLE ISOTOPIC STRATIGRAPHY AND PALEOCEANOGRAPHY IN THE MIDDLE MIOCENE, SOUTHWEST PACIFIC

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Major changes in oceanographic circulation and climate occurred in the Middle Miocene from 14.9 and 12.5 Ma in association with high-latitude cooling and a key step in the development of the East Antarctic ice sheet. A suite of DSDP sites were drilled on the Lord Howe Rise and the Challenger Plateau on DSDP Leg 90 in part to trace the Neogene evolution of intermediate- and deep-waters in the southwest Pacific. High-resolution planktonic and benthic stable isotopic records are presented from six DSDP sites in the southwest Pacific. Sites 588A, 590B, 593, and 594 form a meridional transect at intermediate water depths from 31° to 51°S paleolatitude, while sites 591B and 206 complete a depth transect with 590B at 36°S from 1200 to 3100 m.

High-resolution benthic foraminiferal isotopic records from these sites define the character of the Middle Miocene isotopic signals, including four $\delta^{18}O$ and four $\delta^{13}C$ events useful for global correlation. Two intervals of distinctly low $\delta^{18}O$ at 15.3 and 14.5 Ma were followed by a two-step increase in $\delta^{18}O$ between 14.4 and 12.8 Ma. A rapid (within 200 kyrs) increase in $\delta^{18}O$ at 14.0 Ma was accompanied by the establishment of benthic foraminiferal communities dominated by *Epistominella exigua,* inferred to represent cold deep waters characteristic of the later Neogene. The 14.0 Ma isotopic increase was 0.5‰ greater at the higher latitude Site 1594 (1200m, 51°S) and 0.25‰ greater at Site 591 (2000m, 36°S) than at Site 588A (1350m, 31°S). The $\delta^{18}O$ of *Globoquadrina dehiscens,* an inferred thermocline-dwelling planktonic foraminifer, underwent one increase of 0.5 ‰ at 14.0 Ma at all sites, coincident with the increase in benthic foraminiferal $\delta^{18}O$, suggesting ice growth on East Antarctica increased mean ocean $\delta^{18}O$ by 0.5 ‰ at 14.0 Ma. The Intermediate Water isotopic temperature increase was greater at higher latitudes and at greater depths, signifying increased supply of Antarctic Intermediate Water to the southwest Pacific.

HYDROLOGY OF THE EASTERN MEDITERRANEAN DURING SAPROPEL FORMATION

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The lithology and the oxygen isotopic record of deep sea cores provide evidence for extensive fresh-water input to the eastern Mediterranean during certain periods of glacial retreat. A sapropel, an organic-rich horizon intercalated in the normal marl oozes of the basin, formed between 6,000 and 9,000 yrs BP due either to basin-wide stagnation caused by fresh-water flooding or to increased plankton production because of a runoff-induced reversal in surface circulation. Here we further examine the timing of the pluvially-forced changes in the hydrology of the eastern Mediterranean and the distribution of the freshwater input during the formation of the latest sapropel. AMS radiocarbon dating of sapropel S1 shows that it began to form synchronously (8,600 yr BP) over a very wide area, but that its formation ceased at different times (6,000 to 7,600 yr BP). A high resolution radiocarbon and oxygen isotope record of a core close to the Nile shows that the sapropel began to form when the surface salinity fell to 35, 3.8 psu lower than the present-day value, and stopped forming when it rose again to 36. Oxygen isotope variations in planktonic foraminifera from the sapropel horizon in cores collected throughout the basin demonstrate that the outflow of fresh water from the Nile at this time was confined to the coast of the Levant, as it is at the present time, and that the salinity increased to the west. Salinities were also lower in the area between Crete and North Africa, suggesting that there was at least one other fresh-water source from North Africa. Sapropel formation was associated with the peak of the fresh-water input, but low salinity conditions persisted for a much longer period, suggesting that the fresh-water supply had to be above a certain threshold for a sapropel to form.

PHANEROZOIC CLIMATE MODES AND THEIR ORIGINS IN THE CARBON CYCLE

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Phanerozoic Earth history is divided into four climatic cycles, each about 150 m.y. in length and consisting of a Warm and a Cool Mode (Frakes, Francis and Syktus, 1992). These are, in effect, half-cycles of the Greenhouse-Icehouse phases of Fischer (1981). Here, the division is based on the occurrence in the geological record of more-or-less well-dated tillites and/or ice-rafted deposits (late Ordovician - early Silurian; mid-Carboniferous - late Permian; Late Jurassic - Early Cretaceous; and Mid-Eocene to Recent. In each cycle, the Cool Mode is accompanied by major accumulations of organic-rich marine shales and/or cool deposits on land and by consequential high values of $\delta^{13}C$ in marine carbonate shell material. Near the time of termination of each Cool Mode, organic deposits and $\delta^{13}C$ both peak and then fall markedly. In keeping with the generally accepted correlation of high $\delta^{13}C$ with low atmospheric CO_2 concentration (and vice versa), Warm and Cool Modes can thus be related to global greenhouse/anti-greenhouse effects.

Anti-greenhouse conditions (Cool Modes) appear to originate at times of low volcanic (tectonic) activity which is equated to decreased outgassing; in two cases, initial Warm Mode greenhousing is contemporaneous with increased volcanism (Silurian - Devonian and Late Cretaceous). However, since volcanics actually decreased in the early stages of the Silurian - Carboniferous and Permian - Jurassic Warm Modes, other facts have also affected global climate.

The peak in $\delta^{13}C$ late in Cool Modes can be explained by increased sequestration of organic matter due to increased productivity (including peat) or decreased oxidation in marine environments. We suggest that Cool Modes become increasingly cold through time and that oceanic circulation therefore increased in vigor. These circumstances occurred during low or falling sea levels and culminated when vertical circulation was sufficiently intense to widely oxidize shelf and seafloor organics, thus releasing CO_2 to the ocean-atmosphere system and causing the sharp falls in $\delta^{13}C$. Warming ensued, ending glaciation/ice rafting, in conjunction with decreasing circulation, falling productivity and, eventually, rising sea level and increasing volcanism.

PALAEOCEANOGRAPHIC INTERPRETATION OF THE NORTH ATLANTIC BASED ON BENTHIC FORAMINIFERA (DSDP, LEG 94).

G. Francés (Departamento de Geología, Universidad de Salamanca, Spain), F.J. Sierro, and J. Civis

Benthic foraminifera from DSDP sites 606, 608 and 609B (North Atlantic, between 37° N and 50° N) are studied in order to reveal the main palaeoceanographic changes occurring throughout the Late Pliocene.

More than 170 species have been identified, but only 7-8 taxa are ecologically meaningful for an understanding of the fluctuations in the assemblages and their relation to water masses.

In particular, *N. umboniferus* shows a clear correlation with the AABW, and *P. exigua* and *F. wuellerstorfi* are related to the NADW. Other abundant taxa, such as *G. subglobosa* and *O. umbonatus*, also seem to be connected to the NADW, but local nutrient variations in bottom waters could play an important role in their distribution.

Based on the changes of the benthic foraminifera assemblages we interpret a cooling of the deep waters prior to 2.4 My. Between 3.0 and 2.4 My a mixed AABW-NADW flowed over the bottom at latitudes of sites 606 and 608. The influence of the antarctic component is higher at Site 608, today deeper than Site 606. In both aforementioned sites we have detected a peak in the percentage of *N. umboniferus* coinciding with the Gauss-Matuyama boundary. At the same time an important reduction of the typical NADW members occurs in all the three sites studied, as well as a strong decrease of the benthic-planktic ratio. We interpret this as meaning that during the Late Pliocene glacial maximum the influence of the NADW below 3000 m water depth was null, at least more southern than 50°N latitude. This allowed the northward spreading of the AABW at least to 43°N latitude (Site 608).

After the glacial maximum the oceanographic conditions were similar to recent ones. The Latest Pliocene benthic foraminifera assemblages were dominated by the species characteristic of the current NADW.

A HIGH RESOLUTION RECORD OF OPAL, CARBONATE AND TERRIGENOUS FLUXES IN SUBANTARCTIC S.E. INDIAN OCEAN DURING THE LAST 40,000 YEARS

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High-resolution records of opal, carbonate and terrigenous fluxes have been obtained from a high sedimentation rate core (MD 84-527: 43°50'S; 51°19'E) by normalization to ^{230}Th activity in sediments. This method provides a means of estimating paleofluxes to the seafloor at each point downcore and of distinguishing changes in sediment accumulation due to variations in vertical rain rates from changes in post-depositional sediment redistribution or sediment focussing by bottom currents. We also measured sediment δ^{15}N to evaluate the changes in nitrate utilization in the overlying surface waters associated with paleoflux variations.

Our results show that opal vertical rain rates during the Holocene and stage 3 were much lower than the rates of opal accumulation on the seafloor based on ^{14}C dating. At this particular location, changes in opal accumulation on the seafloor appear to be mainly controlled by changes in sediment focussing rather than reflecting variations in opal rain rates from the overlying water column.

Correction for sediment focussing and the improved time resolution that can be achieved by normalization to ^{230}Th disclose important variations in opal rain rates. We found relatively high but variable opal paleoflux during stage 3, with two maxima centered around 36 ky and 30 ky BP, low opal paleoflux during stage 2 and deglaciation and a pronounced maximum during the Early Holocene. We interpret this record as reflecting variations in opal production rates associated with climate-induced latitudinal migration of the Southern Ocean frontal system. Sediments deposited during periods of high opal paleoflux also have high authigenic U concentrations, suggesting more reducing conditions in the sediment and high $^{231}Pa/^{230}Th$ ratios, suggesting increased scavening by settling particles.

Sediment $\delta^{15}N$ is ca. 1.5‰ higher during isotopic stage 2 and deglaciation. The low opal rain rates recorded during that period appear to have been associated with increased nitrate utilization. This suggests a lower nitrate supply rate to surface waters, possibly associated with water column stratification produced by melting icebergs.

HIGH RESOLUTION PROFILES OF ^{10}BERYLLIUM, ^{230}THORIUM AND ^{231}PROTACTINIUM OF TWO SEDIMENT CORES FROM THE GALAPAGOS MICROPLATE, EASTERN EQUATORIAL PACIFIC: CLIMATIC AND GEOCHEMICAL INFORMATION

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Two sediment cores from the Galapagos microplate (KLH 068: 1°13'91"N, 101°36'73"W; 2870 m water depth, 202 cm length; and KLH 093: 1°29'97"N, 102°03'81"W; 3259 m water depth, 305 cm length) were analyzed at high resolution for the concentration of ^{10}Be (AMS), ^{230}Th and ^{231}Pa (both α-spectroscopy), Al, Fe and Mn. Applying different methods of dating like $^{230}Th_{ex}$, $\delta^{18}O$-stratigraphy and ESR-spectroscopy of planktonic foraminifera, the average sedimentation rate of core KLH 093 was 3.22±0.5 cm/ky. For core KLH 068, an average rate of 3.14±0.6 cm/ky was calculated (omitting a sedimentary hiatus of about 26 ky). Thus both cores cover a time span of about 100 ky.

From the $^{10}Be/^{230}Th_{prod}$ ratios(the ratio of the ^{10}Be- and ^{230}Th-fluxes that exceed production and normalized to production) and the $^{230}Th_{ex}/^{231}Pa_{ex}$ ratios it can be concluded that hydrothermal activity was one of the main factors responsible for the strong scavenging of the measured radionuclides during the last 100 ky. The Fe concentrations suggest that no strong variations of the hydrothermal activity occurred during this period. However, according to the Mn concentrations there was either a decrease in hydrothermal activity or the Mn produced by the Mid-Ocean Ridge was not deposited at the core locations during isotope stages 2 and 3.

The Galapagos microplate cores show a decrease in deposition of the radionuclides ^{10}Be and ^{231}Pa in times of stronger paleoproductivity with aluminosilicates and biogenic opal being the scavengers of ^{10}Be and ^{231}Pa. We think that this is due to an effect of lateral scavenging affecting these elements at a distance of nearly 2000 km from the upwelling centers. Maxima in bioproductivity coinciding with increasing upwelling intensity off Peru as shown by Oberhänsli et al. (1990) cause enhanced boundary scavenging and thus a decrease in deposition at the core locations.

HIGH RESOLUTION MEASUREMENTS OF ^{231}PROTACTINIUM IN MANGANESE-CRUSTS

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The concentration of ^{231}Pa (and of ^{230}Th) in the Mn-crust of core VA-13-2 (9° 25' N, 146° W, 4830 m) from the Pacific Ocean was measured at high depth-resolution (0.05 mm) to a depth of 0.8 mm, corresponding to an age of approx. 150 ka B.P.

The mean growth rate derived from the relationship of $^{230}Th/^{231}Pa$ with depth is 5.6 ± 0.5 mm/Ma. It corroborates an earlier estimate of 6.2 ± 0.4 mm/Ma derived from the profile of ^{230}Th. The ratio of Th/Pa at the surface of the Mn-crust amounts to 11.8 suggesting direct seawater precipitation of Mn- and Fe-oxides.

In contrast to the constant flux of ^{230}Th, the flux of ^{231}Pa shows minimum values during ^{18}O-stages 3 (24 to 59 ka) and during stage 4 (59 to 74 ka). We attribute these low ^{231}Pa fluxes to periods of stronger scavenging activity in the equatorial high productivity zone during glacial stages.

A simple but very efficient method for the measurement of ^{231}Pa was developed. It consists of one ion exchange step followed by electrodeposition of Pa (chemical yield better than 50%). The concentrations of ^{231}Pa (α-decay) and of the spike ^{233}Pa (β-decay) are measured simultaneously with a semiconductor detector.

MAGNETOSTRATIGRAPHY OF LATE QUATERNARY ARCTIC OCEAN SEDIMENTS, II: THE LOMONOSOV RIDGE, MORRIS JESUP RISE, AND YERMAK PLATEAU

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One of the main sampling areas of the international expedition ARCTIC '91 with RV POLARSTERN in the central Arctic Ocean was the Lomonosov Ridge. Six long sediment cores recovered at about 88°N and 140°E can be correlated on the basis of their downcore variations in magnetic susceptibility over a distance of 110 km. This correlation can be used to estimate relative sedimentation rates which are somewhat lower at the eastern flank of the ridge as compared to its top. The magnetostratigraphic results of Core PS 2185-6 KAL from the top of the Lomonosov Ridge (water depth 1052 m) are used to establish a first order time frame.

Core PS 2185-6 KAL and Core PS 2200-5 KAL from the top of the Morris Jesup Rise (water depth 1073 m; 85°N, 14°W) revealed a striking similarity in downcore variations of physical properties and stable inclination, implying a similar late Quaternary sedimentation regime at these two sites, about 800 km apart.

High-quality magnetostratigraphic results could also be obtained for Core PS 2212-3 KAL taken at the Yermak Plateau (82°N, 16°E). Intervals of negative inclination are identified as short Brunhes Epoch polarity events: Mono Lake (25 ka), Laschamp (40 ka), Norwegian-Greenland Sea (70 ka), Blake (115 ka) and Biwa I (180 ka). This series of events provides an excellent time base for Site 2212, resulting in sedimentation rates of 3 to 4 cm/kyr for oxygen isotope stages 1 to 5 and 6 cm/kyr for stage 6. These data give additional evidence for a late Quaternary high deposition sedimentation environment in parts of the eastern Arctic Ocean.

PALEOGEOCHEMICAL RECORDS OF SOUTHERN OCEAN PRODUCTIVITY, NUTRIENTS, AND SEA ICE -- LINKS TO GLACIAL-INTERGLACIAL ATMOSPHERIC CO_2 CHANGES

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An alternative paradigm is emerging from Southern Ocean sediment cores which suggest that the glacial Antarctic nutrient (and iron?) scenarios may be alive and well in the subantarctic. Earlier evidence based on opal accumulation rates, $(Ge/Si)_{opal}$, and $\delta^{13}C_{pachy}$ is now supported by sediment records of $\delta^{15}N_{org}$ (Francois, Altabet, Burckle), $\Delta\delta^{13}C_{foram}$ (planktonic - benthic) (Howard, Prell), and $^{231}Pa/^{230}Th$ (Kumar, Gwiazda). These paleoproxies support the notion of higher glacial (lower interglacial) production (more efficient nutrient utilization) in the subantarctic (north of the PFZ) and lower glacial (higher interglacial) production in the Antarctic (south of the PFZ). One scenario to consider is a "seesaw" model in which glacial to interglacial fluctuations in seasonal sea ice cover -- the extent and duration of the late summer meltback -- modulates Antarctic production and nutrient utilization and thus the northward transport of unutilized surface water nutrients upwelled in the Antarctic to the subantarctic. This effect, rather than shifts in hydrographic fronts, may produce the well-known ~5° northward migration of glacial sediment opal contents and microfossil assemblages ("PFZ migration").

If one believes this scenario, then high resolution opal records north and south of the PFZ reflect high frequency mirror-image changes in silica utilization north and south of the PFZ, and may provide chronostratigraphic correlations in the Antarctic beyond ^{14}C limits and in sediments devoid of foraminifera. Long records in the Antarctic (RC13-259) and Subantarctic (ODP 704) indicate that this seesaw pattern has operated during at least the last 12 climatic cycles, and that stages 9 and 11 in the Antarctic-Subantarctic may have been more "asymmetric" than the Holocene or stage 5e.

The principle difficulties with this paradigm are dissolution effects on the opal records, uncertainties in diatom fractionation for $(Ge/Si)_{opal}$, lack of knowledge of the extent and duration of glacial summer sea ice melt back in the Antarctic, and explanations for the conflicting evidence: $(Cd/Ca)_{pachy}$ and ice core DMS (MSA and nss-SO_4).

SEDIMENTS OF THE ICELAND-FAROE RIDGE: ENVIRONMENT-CONTROLLED, BIOGENIC SEDIMENT STRUCTURES

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Although our knowledge on the distribution of biogenic sediment structures in deep-sea sediments has largely increased in the last decade, the main aim justifying these endeavours, i.e., their application to paleoceanographic reconstruction of environments, is still far from being achieved. Our approach in the present project is based on the analysis of biogenic sediment structures

from sediment cores (up to 30 x 30 cm cross-section) representing different environmental settings with preferably contrasting parameters, such as high/low sedimentation rates (resp. organic carbon content, carbonate content, bottom and pore water degree of anoxidity, etc.). The biogenic sediment structures are determined from X-ray radiographs and computer tomographic sections. It is a concern of the poster to display examples of this technique in the study of ichnofabrics.

On the Iceland-Faroe Ridge, whose sedimentological context is presented in a parallel poster, we encounter favorable prerequisites for this conception: the contrasting north and south slopes, regions differently affected by bottom currents, and current-controlled asymmetric sediment distribution in a topographically complicated channel system on the south slope comprising both glacial and post-glacial sediment fillings. It is shown that the high diversity of the biogenic structures ("ichnoguilds") of the southern slope contrasts with the themonotonous northern slope and is correlated with correspondingly variable environment parameters. Within the asymmetric channel deposits, the contrast of highly diverse and monotonous ichnoguilds repeats at a second order scale at opposite channel slopes in relation to sedimentological parameters in the alternating vertical sequence. Characteristically, Scolicia-dominant ichnofabrics are related to fine-grained and rapidly accumulated sediments, in contrast to various assemblages of biogenic structures at the low-accumulating facies correlated with fluctuating carbonate and sand content.

THE PRECISE TIMING AND AMPLITUDE OF SEA LEVELS BETWEEN 85 AND 230 ka FROM ^{230}Th AGES OF FOSSIL CORALS FROM BARBADOS, WEST INDIES

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Recent development of high-precision techniques for measuring ^{230}Th and ^{234}U have provided the opportunity to obtain precise records of late Quaternary sea level changes by dating fossil corals. Given the analytical precision, the major limitation becomes potential shifts in isotopic composition that result in age shifts. Previous work indicates many fossil corals from Barbados have initial δ^{234}U values above modern values (δ^{234}U =149.7 ± 1.5, mean and $2\sigma_{population}$ of 4 samples <2500 yr old), suggesting open system behavior.

We sampled several terraces and a well-preserved ancient beach deposit along a transect in the Clermont Nose area of Barbados. The beach deposit, at 90 m elev., contains coral cobbles in an unconsolidated carbonate sand matrix. Several cobbles from this deposit are the oldest samples to have an initial δ^{234}U within error of modern values, suggesting that their ages are accurate. They have an age range of 193.5 ± 2.8 to 200.8 ± 1.5 ka and an initial elev. of between 1 and 16 m above present sea level (SL). Reef-crest and fore-reef deposits at 78 and 83 m give similar ages. We believe that these deposits correlate with oxygen-isotope stage 7.1 (the end of the penultimate interglacial). A terrace at 65 m elev. gives an age of 228 ± 5 ka with an initial δ^{234}U of 189. This older age and low elev. suggest a SL low of -38 to -24 m, which may correlate with isotope stage 7.4. A deposit 18 m below the crest of the last interglacial terrace contained a cobble with an age of 117 ± 1 ka, constraining the timing of the end of the last interglacial. This implies a rate of SL drop of 1.8 to 4.0 m ka^{-1}. North of Clermont Nose, two samples from the stage 5a terrace suggest that the reef developed (at 12 to 17 m below present SL) between 88.6 ± 0.9 and 84.6 ± 0.4 ka.

The timing of the penultimate interglacial and the stage 5a interstadial overlap peaks in 65°N insolation, and the 228 ka SL low and the 117 ka SL drop coincide with minima in 65°N insolation, suggesting Milankovitch forcing for periods of major climatic change. It appears that lags between insolation and SL rise are small, whereas lags between insolation and SL fall are significant for the last three interglacials.

REWORKED NANNOFOSSILS IN QUATERNARY SEDIMENTS FROM THE CENTRAL ARCTIC: IMPLICATIONS FOR PALEOBIOGEOGRAPHY AND PALEOCLIMATES

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Two Jurassic, 77 Cretaceous and 40 Paleogene nannofossil species have been recorded in numerous short sediment cores from the central Arctic Ocean. They provide insights into nannofossil paleobiogeography, paleoclimates, sediment distribution on the shelf areas surrounding the Arctic Ocean and Quaternary sediment deposition patterns.

The reworked nannofossils are concentrated at levels where *in situ* assemblages are most common. Specimens with mutually exclusive stratigraphic ranges occur together. This suggests that the reworked specimens do not primarily reflect the local bedrock, but are transported to the central Arctic Ocean from the surrounding shelves. This mechanism of transportation and deposition is most active during warmer time periods. Sea ice provides a possible means.

The oldest nannofossils recorded are *Crucirhabdus primulus* Prins in Rood, Hay & Barnard and *Parhabdolithus liasicus* Deflandre from the Lower Jurassic. This is the furthest north that these species have ever been recorded.

The Lower Cretaceous is represented by eight species restricted to that interval, together with other longer-ranging taxa. The presence of *Micrantholithus speetonensis* Perch-Nielsen is the first record of this species outside NW Europe, and indicates the occurrence of Valanginian strata. The Lower Cretaceous species observed are all typical of temperate to high latitude assemblages of both the southern and northern hemispheres.

The nannofossils reworked from the Upper Cretaceous strata are the dominant component of the assemblages. *Nephrolithus corystus* wind is recorded in the northern hemisphere for the first time. However, some of the distinctive high latitude species present in the southern hemisphere have not been observed in the Arctic sediments.

Paleocene, Eocene and Oligocene nannofossils are also recorded in the cores. The presence of discoasters and sphenoliths in such high latitudes suggests warmer conditions than at similar latitudes in the southern hemisphere.

REGIONAL AND TEMPORAL CHANGES IN HYDROTHERMAL SEDIMENTATION IN THE LAU BACK-ARC BASIN, SW PACIFIC

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Sedimentological and geochemical investigations of surface samples and piston cores were undertaken in order to study regional and temporal variability of hydrothermal metalliferous sediment. The chemical composition of the bulk sediment was determined by XRF-analysis. Additional surface samples were subjected to selective leaching for Fe, Mn, Cu, Zn, and Ni. To quantify the variability of sediment components downcore, mass accumulation rates (= flux) of components were estimated.

Results from reductive leaching show that only a small proportion of the total Fe (XRF-data) was dissolved (28%). Large amounts of undissolved Fe indicate large amounts of silicate debris. On the contrary most of the total Mn and Ni of the sediment was leachable (71%/79%). Leachable Fe and Mn occur as colloidal amorphous oxihydroxides, formed by precipitation from hydrothermal solutions.

Spatial variability of Fe-Mn-oxyhydroxides indicate fractionation of Fe and Mn during transport. Decreasing Fe/Mn-ratios from the spreading centers to the basins implies settling of Fe near the vents, whereas dissolved Mn may be transported over long distances and accumulate in basinal sediments.

Sediments in the southern Lau Basin were enriched in leachable Mn-oxihydroxides by a factor of 2, and may be caused by the chemical composition of the lava types and by high water-rock ratios due to the rugged andesitic basement in the southern Lau Basin, favoring the leaching of metal ions .

Temporal variations of the flux of Mn were indicated: for the last 400 ka, flux rates of Mn range between 5-40 mg/cm^{2}ka in the northern and 5-90 mg/cm^{2}ka in the southern Lau Basin (carbonate-free). Slightly higher amounts of 10-110 mg/cm^{2}ka (NLB) and 10-130 mg/cm^{2}ka (SLB) were reported for the time span 400-800 ka B.P. An elevated flux of Mn was observed during the interglacial periods, reflecting short-scale Milankovitch cyclicity (100 ka). Also large-scale cyclicity of MAR was indicated: the accumulation fluctuates on a high level during isotope stages 5-11 and 17-21, while it was lower during stages 12-16.

The observations suggest that the accumulation of hydrothermal derived Mn is partly controlled by Quaternary climatic cycles.

EARLY GLACIAL DEPOSITS IN ICELAND: IMPLICATION FOR CLIMATIC CHANGES IN THE NORTH ATLANTIC

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The location of Iceland on the Atlantic Ridge system, directly below the Arctic Circle, provides a unique terrestrial setting to study and understand the climatic changes during the Quaternary. Preservation of glacial deposits is common in Iceland due to high frequency of effusive eruptions forming widespread lava flows which effectively shield underlying strata from subsequent erosion. The characteristic stratigraphy in Iceland shows numerous basaltic lava flows interbedded with sediments representing diverse depositional environments. Paleomagnetism and K-Ar dating provide absolute ages for most of the formations.

Deep sea paleoclimatic records show that the Quaternary climate around Iceland was sensitive to the shifting positions of the Polar Front. Studies on several key sections in Iceland indicate that similar oscillations are reflected in the late Pliocene and early Pleistocene stratigraphy. They provide important information about local and regional patterns of glaciation which are key factors in understanding the linkage between orbital forces and climatic responses. Detailed documentation of vertical and lateral facies associations at various sites in Iceland enabled delineation of the onset of glaciation. A fairly distinct trend is identified during the Pliocene-Pleistocene transition showing a progressive growth of an ice sheet from southeast to north and west. A total of seven glacial events are recognized within an interval extending from the upper part of the Gauss magnetic epoch to the Olduvai magnetic event. In addition, ten glacial events have been identified in northern Iceland between the Olduvai event and Brunhes epoch. Comparison of the first appearance of glacial deposits at various locations in Iceland implies that the onset of glaciation was gradational rather than synchronous over the whole of Iceland and might have taken several hundred thousands of years to extend across the island. Current studies in southern Iceland include detailed analysis of sedimentary horizons deposited during the Brunhes magnetic epoch. These studies will undoubtedly contribute to the knowledge of the glacial history of Iceland and the North Atlantic by comparison with the latest deep-sea record of glacial-interglacial cycles.

SEA ICE VARIABILITY AND PALEOPRODUCTIVITY CHANGES IN THE LATE QUATERNARY SOUTHERN OCEAN

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The Southern Ocean is characterized by a largely continuous belt of high biogenic silica accumulation. In the Atlantic sector average Holocene opal accumulation rates are around 10 g cm^2 ka^{-1} within the belt. Today the silica belt is bounded to the south by the winter sea-ice edge and to the north by the Polar Front where opal accumulation rates calculated from surface sediments drop below 1 g cm^2 ka^{-1}. In addition, time-series, sediment-trap studies (compare poster Gersonde and Zielinski) show that export productivity in the Southern Ocean is significantly decreased in pelagic cold water areas that are seasonally covered by sea ice. This indicates that both the location of the Polar Front and the winter sea-ice edge are crucial determinants for the spatial distribution of the Antarctic belt of high biosiliceous export productivity.

Accumulation rates of biogenic opal, as well as the abundance pattern of the radiolarian taxon *Antarctissa*, which can be used as a tracer for past productivity, were studied on a sediment core transect across the Antarctic Circumpolar Current. The results suggest distinctly lower paleoproductivity during glacial times south of the present Polar Front which was linked to the northward migration of the sea-ice edge up to the area of the present Polar Front. This estimate of the past sea-ice distribution is based on diatom sea-ice indicator species (compare poster Zielinski and Gersonde). Apparently the high productivity belt, at present bounded by the Polar Front, did not migrate to the north during glacial time periods, as no distinct glacial/interglacial variations of the paleoproductivity tracers could be found in cores from the northern Polar Frontal Zone. Indeed, paleoproductivity was relatively enhanced during glacial times in the area of present subantarctic waters.

It can be concluded that paleoproductivity in the Southern Ocean was generally lower during glacial time intervals. This finding can be linked to the increase of sea-ice coverage. Thus productivity changes in the Southern Ocean were not responsible for glacial reduction in atmospheric CO_2 concentrations.

DIATOM PARTICLE FLUX IN THE SOUTHERN OCEAN (ATLANTIC SECTOR)

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The study of diatom particle flux obtained during short-term and annual sediment trap experiments at seven localities in the Southern Ocean provides information for better evaluation of paleoceanographic signals recorded as diatom assemblages in late Quaternary southern high-latitude sediments. The diatom flux, which represents a signal of export productivity, is characterized by significant seasonal and interannual variations. In the Seasonal Ice Zone (SIZ) the diatom flux occurs in pulses, accounting for 70-95% of the total annual flux during austral summer, with a duration of only 2-9 weeks. The annual values of vertical diatom flux range between 0.26×10^6 and more than 26×10^6 valves m^{-2}. Interannual differences range over a factor of ten.

Lowest flux values were measured in pelagic areas of the SIZ. In these traps the diatom assemblages are dominated by sea ice-related taxa. Exceptional are the results obtained in the vicinity of Maud Rise, where relatively high flux rates were recorded and the species composition is dominated by a taxon (*Nitzschia kerguelensis*) which preferentially dwells in waters north of the SIZ. This pattern can be explained by the local oceanographic situation at Maud Rise, which is characterized by doming of warmer and saltier waters, according to Gordon and Huber (1984).

The sediment trap study shows that the southern high-latitude diatom flux is highly variable. Controlling factors of quantity, timing and pattern of the vertical flux are sea ice distribution, hydrographic conditions and occurrence of grazers. The paleoceanographic signals transferred to the ocean floor are produced during a short time span during austral summer. The presence of winter sea ice is documented by a signal produced during summer.

DISCRETE BARYTE PARTICLES AND BARIUM AS TRACERS OF PALEOPRODUCTIVITY IN SOUTH ATLANTIC SEDIMENTS

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The use of barium as a tracer of paleoproductivity is a well-established tool for the determination of relative variations in the productivity of the oceans.

Geochemical analyses as well as X-ray diffraction measurements were carried out on five sediment cores from the eastern Angola Basin and the Equatorial Divergence of the South Atlantic. Baryte concentrations were calculated from total barium concentrations after subtracting the estimated barium background supplied by "non-baryte" barium carriers. Baryte concentrations assessed by this geochemical method show a good correspondence with baryte concentrations determined by quantitative XRD-measurements. Baryte proved to be the main carrier of barium in the pelagic cores, contributing up to 90% to the total barium concentrations in the sediment, while clastic material provides an important source of barium at sites closer to the African continent. Baryte concentrations were transferred to baryte accumulation rates to eliminate diluting effects of varying inputs of terrigenous and biogenic material.

Baryte accumulation rates show cyclic variations with maxima corresponding to glacial and minima to interglacial stages. Assuming a linear relationship between baryte accumulation and paleoproductivity, an increase in paleoproductivity by the magnitude two to three can be calculated for the last glacial period (stage 2) in the eastern Angola Basin (Congo Fan). In the equatorial upwelling area baryte accumulation rates representing paleoproductivity were four to six times higher in the last glacial period compared to present.

Higher productivity at the Equatorial Divergence during the last glacial period may indicate intensified upwelling induced by stronger trade winds, supplying more nutrients to the productive surface layer. In the eastern Angola Basin a northerly advection of the Benguela Coastal Current is a likely reason for higher production rates in glacial periods.

SENSITIVITY OF MODELED CRETACEOUS COASTAL UPWELLING TO MILANKOVITCH SCALE INSOLATION VARIATION

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Certain Cretaceous Period marine formations (e.g., Cenomanian-Turonian Age U. S. Western Interior Seaway) show long geologic records of rhythmic sedimentation - alternating bioturbated marlstones and laminated shales. It has been proposed that these types of sediments were laid down in response to climate changes produced by the cyclic insolation forcing created by variation in Earth-Sun relationships (Milankovitch scale variation). One proposed process which might produce this type of cyclic sedimentation is rhythmic productivity change caused by cyclic variation in upwelling.

For the past several years, we have used the National Center for Atmospheric Research Community Climate Model to examine the sensitivity of Cretaceous climate to change under different Milankovitch scale insolation forcing conditions. To examine the effect of insolation change on coastal upwelling, the surface wind field was resolved into zonal and meridional components for each simulation. If the wind component was properly oriented in relation to the model coastline, it was assumed that a mean wind stress $\geq$ 2.0 meters/second would produce sufficient Ekman divergence to sustain coastal upwelling. Statistical significance was determined using the null hypothesis with the Student$_t$ distribution to $\alpha_{0.005}$.

Model simulations suggest that coastal upwelling was widespread in the summer hemisphere and became more intense under higher insolation forcing. During Northern Hemisphere summer, upwelling could have been present in the Cretaceous Arctic Ocean and comparison of simulations under different insolation forcing suggests that cyclic variation in upwelling might have occurred in both the Western Interior Seaway and the Paris Basin. During Northern Hemisphere winter, simulation comparisons suggest that cyclic variation in upwelling might have occurred in the South Atlantic Ocean.

A MODEL OF THE EVOLUTION OF ATMOSPHERIC CO_2 DURING MESOZOIC AND CENOZOIC TIME

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A numerical model (François and Walker, *Am. J. Sci.*, **292**, 81-135, 1992) of the major biogeochemical cycles (carbon, sulfur, calcium, magnesium, phosphorus and strontium) and of their evolution over geological time is used to

investigate the role of seafloor basalt weathering in the control of atmospheric CO_2 over time scales of several million years. The model consists of a biogeochemical model coupled with an energy balance climate model.

According to Raymo (*Geology,* **19**, 344-347, 1991), the changes in the $^{87}Sr/^{86}Sr$ isotopic ratio of ancient seawater recorded in carbonates would indicate past changes in the weathering rate of continents largely due to mountain uplift and continental collisions. However, the strontium isotopic signal is actually a mixture of changes in both the intensity of weathering and in the mean isotopic composition of the weathered rock. Here, we tentatively use the $^{143}Nd/^{144}Nd$ record of ancient seawater to estimate the change in the isotopic composition of the weathered rock; the $^{87}Sr/^{86}Sr$ ratio is used to derive the history of the weather of the continents.

From the biogeochemical model, it is then possible to calculate the history of atmospheric carbon dioxide over the last 140 My, provided that a rate law is given for the weathering of seafloor basalts, a carbon sink which is not well-known, but that we expect plays a key role in the evolution of atmospheric CO_2. As a sensitivity test, various formulations are adopted for this rate law. The calculated CO_2 evolution is compared to that recently reconstructed from geological records of the carbon isotopic fractionation during photosynthesis by marine organisms. It is shown that it is possible to reproduce with the model these reconstructed past changes in atmospheric CO_2, as well as the observed fluctuations of the calcite compensation depth in the global ocean. These results suggest that seafloor weathering (contrary to continental weathering) is a likely controlling process of atmospheric CO_2 over time scales of several million years.

ICE-RAFTING OF TERRESTRIAL TILL BALLS INTO THE GREENLAND SEA

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In two sediment cores from the bottom of the Greenland continental slope, large (2-5 cm diametre) balls of poorly-sorted coarse material were found. These were analyzed in terms of grain shape, grain roundness, and mineralogic and biogenic content; radiographs of the surrounding matrix were examined to determine evidence of ice-rafting or bottom currents. Several balls were preserved and sectioned. All studied parameters indicate that the Greenland Sea balls are armored and unarmored till balls. The armor consists of coarse material surrounding finer-grained core sediments and forms in a manner similar to that of armored mud balls, which are found in ephemeral streams and on beaches backed by cliffs of fine-grained material.

The shape of the balls themselves is either spherical or cylindrical. It is hypothesized that the spherical ones formed in a fluvial (polymodal) environment while the cylindrical balls formed in the littoral (uni- or bimodal) environment. The process for the spheres is as follows: Till cliffs (possibly a moraine) were eroded by a (meltwater?) stream. Frozen angular blocks of till fell into the stream; rounding and armoring occurred when the blocks were rolled along the coarser-grained stream bottom. The cylindrical balls formed similarly, by rounding and armoring of mud blocks from cliffs backing a beach.

Sectioning of the Greenland Sea balls shows that many have a concentric armored structure, which would be indicative of formation as described above. Two do not; they may have been too coarse-grained for armoring and were rounded by abrasion instead.

Rafting (by shorefast ice) of the till balls occurred relatively soon after their formation. Upon melting of the ice, the balls sank to the bottom of the sea; they were saved from disaggregation during the descent by the fact that they were still partially frozen.

If the above hypothesis is correct, it would be the only instance of such balls being found in the deep-sea. An *in situ* (marine) formation is unlikely due to difficulty in creating cohesive balls underwater and to the total lack of biogenic material in the balls.

AEOLIAN DEPOSITION OF COARSE-GRAINED SEDIMENT INTO MARGINAL SEAS: THE VIEW FROM SYLT

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The tidal flats immediately east of the northernmost portion of the island Sylt on the German North Sea coast are much coarser-grained than tidal flats elsewhere in the Wadden Sea. West of the coarse-grained flats are large (up to 35 m high) sand dunes that moved slowly downwind until they were "fastened" by vegetation planting in the mid to late 20th century. This study is concerned with the question whether the coarse sediments from the dunes influence the tidal flats.

Grain size measurements of sediment from a beach on Sylt's western coast, from the sand dunes, and from the tidal flats on the eastern coast of Sylt show that the beach and the dunes extensively affect the flats. While the mean grain size of sediment in normal tidal flats is between 63 and 125 μm, the value for tidal flats in the study area is 250-300 μm, similar to values of 300-350 μm for the beach and 200-500 μm for the dunes.

Winds of 1000-2000 cm/s occur frequently on Sylt. These are capable of carrying the coarse-grained sediments found in this study from the beach to the dunes and from the dunes to the tidal flats. This transport must occur *in suspension* because groundwater lakes and other obstacles in the dune area would prevent saltating sediments from being carried further. Transport by water can be ruled out; although a tidal inlet is in the region, the study area is located far enough "upstream" that the inlet's currents are incapable of transporting sand into the study area.

The results of this study have implications for coarse-grained (sand-sized) sediments found in cores from the ocean bottom in marginal seas. Aeolian transport of suspended sediment at Sylt occurs over a few kilometers. Thus sand-sized deposits from marginal seas, which were previously considered to be "too coarse" to have been transported by the wind, may have been deposited by precisely that process.

PALEOCEANOGRAPHY OF THE JAPAN AND OKHOTSK SEAS DURING THE LAST GLACIATION AND THE HOLOCENE

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Shallowing of the Tsushima and Tsugaru Straits and their position relative to the Polar Front stipulate paleoceanographic sensitivity of the Japan Sea to changing of inflow of warm water of Kuroshio and cold water of Oyashio under glacio-eustatic sea-level variation and shifting of the Polar Front in the past.

$\delta^{18}O$ and $\delta^{13}C$ data of the planktic and benthic foraminifera (Gorbarenko,1987; Oba et al., 1991) show that during the last glacial maxima, a strong decrease in Kuroshio water inflow, and the dominance of precipitation and runoff over evaporation led to desalinization of surface waters and to poor ventilation in deep and bottom waters. At the beginning of the transgression Oyashio cold water started to flow into the Japan Sea. Then, during sea-level rise and northward Polar Front displacement, inflow of Kuroshio warm water increased and Oyashio cold water decreased.

The paleoceangraphy of the Okhotsk Sea during the last glaciation and the following warming were defined by paleoenvironmental conditions in the northwestern Pacific and the Bering Sea, which were considerably influenced by the origin of the Bering Bridge and by adjoining land. In the cores from the Okhotsk Sea, as well as from the northwestern Pacific (Kallel et al., 1988; Keigwin et al., in press), and the Bering Sea at the end of Termination Ia and Ib of $\delta^{18}O$ records paleoceanographical changes leading to the better preservation of carbonate tests at the bottom and to higher $CaCO_3$ contents in the sediments. The change in chemical conditions in deep and bottom water at that time was probably caused by desalinization of the Bering Sea surface water during melting of the glaciers (Sancetta et al., 1985) and weakening of the aeration of deep waters in the region.

SOUTHWARD EXPANDINGS OF THE SOMALIAN UPWELLING DURING THE LATE QUATERNARY

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Intensity changes of the Somalian upwelling during the last 400,000 years are recorded in two cores: MD 85674 (3°11.22 N-50°26.3 E, 4875m depth) beneath the 5°N gyre, and MD 85668 (0° 01.0 S-46°02.3 E, 4020m depth) under the Equator. An upwelling radiolarian index based on quantitative changes of radiolarian species endemic to upwelling areas, the relative abundances of planktonic foraminifers *N. dutertrei, G. menardii, G. bulloides,* and the $\delta^{13}C$ changes of *N. dutertrei* are used as upwelling intensity proxies. The MD 85674 core data (restricted to the last 160,000 years) indicate that upwelling activity of the 5°N Somalian gyre was maximal during transition between isotope stage 6 and 5, during isotope stage 3, and transition between isotope stages 2 and 1. Synchronous (although less pronounced) variations of the same markers in core MD 85668 are indicative of a southward expansion of the Somalian gyre during intervals of intensified upwelling activity. Using the same proxies in older intervals of core MD 85668 allows us to reconstruct the variations of the Somalian upwelling back to 400,000 years. It appears that the Somalian upwelling was intensified during transition between isotope stages 6 and 7, during isotope stages 8 and 9, during transitions between stages 9 and 10, and also 11 and 12. The intervals of higher upwelling intensity are well-matched by intervals of higher organic production in the coastal upwelling off Peru. The rather good synchronism between the Peruvian, the Arabian, and the Somalian upwelling avariations suggest a common climatic control, probably associated with the evolution of the Southern Oscillation.

PATTERNS OF ICE-RAFTED DETRITUS IN THE GLACIAL NORTH ATLANTIC (40-55°)

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A study by Heinrich (1988) rekindled interest in the timing of the influx of ice-rafted detritus in North Atlantic sediments. In a set of cores of the Northeast Atlantic Basin (≈47°N, 20°W), we have resolved six well-defined, ice-rafted detritus layers over the last 70 ky at approximately 11 ky intervals. Broecker et al. (1992) described these events in a high-resolution study of a neighboring core (ODP-609), demonstrating that these "Heinrich Layers" were not an exceptional feature; moreover, they reported AMS radiocarbon dates for the three most recent events (13.4-14.5ka, 18.9-21.4ka, 25.6-29.2ka).

In this paper, we present a rapid method to study the distribution of these events (both in space and time) using whole core low-field magnetic susceptibility. We report on approximately 30 cores covering the last 150 to 250 ka. Well-defined patterns of ice-rafted detritus appear during periods of large continental ice sheet extent, although not always within their maxima. Most of the events may be traced across the North Atlantic Ocean. For the six more recent Heinrich layers (HL), two distinct patterns exist: HL1, HL2, HL4 and HL5 are distributed along the northern boundary of the Glacial Polar Front, over most of the North Atlantic between ≈40° and 50°N; the 3 and HL6 are more restricted to the central and eastern part of the northern Atlantic. The Nd-Sr isotopic composition of the material constituting different Heinrich events indicates the different provenance of the two patterns: HL3 and HL6 have a typical north Europe-Arctic-Icelandic "young crust" signature, and the others have a large component of northern Quebec and northern West-Greenland "old crust" material. These isotopic results, obtained on core SU-9008 from the North American basin, are in agreement with the study by Huon and Jantschik (1992), who used K-Ar dating of silt-and clay-size fractions of an eastern basin core (Me-6889), and confirmed the large spatial scale of these events and the enormous amount of ice-rafted detritus they represent.

BIOGEOGRAPHIC DISTRIBUTION OF *BOLBOFORMA* IN UPPER EOCENE/OLIGOCENE MARINE SEDIMENTS IN THE SOUTHERN HEMISPHERE

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The members of the genus *Bolboforma* (Daniels and Spiegler, 1974) are marine microfossils (probably protophytic algae) which are mainly limited to middle and high latitudes in both hemispheres. *Bolboforma* have been observed in lower Eocene to lower Pliocene sediments and yield a useful biostratigraphic tool, mainly in high latitudes, where the biostratigraphic value of other biozonations is restricted.

The object of this study is to demonstrate the biogeographic distribution changes of *Bolboforma* in upper Eocene to Oligocene marine sediments in the southern hemisphere. Therefore, *Bolboforma* data of ODP Leg 113 (Kennett and Kennett, 1991), ODP Leg 114 (Spiegler, 1991), and of ODP Leg 120 (Mackensen and Spiegler, 1992) are compared and correlated with the evaluated data of DSDP Legs 29, 36, 71 and 90 and represented in palinspastic maps in time spans of about 6 My.

In the lower-most Oligocene, a formation of a continental ice sheet on Antarctica is postulated, which is mainly derived from a rapid, positive shift of the oxygen isotope values in tests of marine calcareous microfossils. The distribution of *Bolboforma* reacts upon this well-known climatic deterioration in the southern hemisphere at about 35.9 Ma in dependent of latitudes.

In late Eocene (40 Ma) *Bolboforma* shows a wide-spread extension in latitude. A successive, south to north disappearance of *Bolboforma* in the sites just after the oxygen isotopic shift at 35.9 Ma can be recognized. At about 34 Ma the biogeographic distribution of *Bolboforma* is only restricted to a small belt in middle southern latitudes. This characteristic distribution can be explained as a reaction of *Bolboforma* to a progressive cooling northward in the southern hemisphere.

$\delta^{18}O$-VARIATIONS IN DIAGENETIC SEQUENCES FROM ATLANTIC SEDIMENTARY BASINS

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Stable isotope analyses on DSDP/ODP-samples from Atlantic Ocean basins have been carried out to reconstruct the formation temperatures of calcite and chert at various burial depth levels. The effect of geothermal anomalies on authigenic mineralization.is of special interest in this context.

The carbon isotopic composition of concretionary calcite ($\delta^{13}C$=0.4 to 2.9‰) suggests dissolved primary marine carbonate to be the source for the diagenetic calcite. Using the calcite/water equilibrium, the oxygen isotopic composition of the calcite indicates maximum formation temperature of 50°C. It can be seen that the diagenetic carbonate formation gives no hints on unusually high heat flow in North Atlantic ocean basins. This is also obvious from the thermal gradients. Values of 3 to 6°C/100m derived from the formation temperatures are similar to the geothermal gradient.

On the other hand the oxygen isotopic composition of concretionary chert samples could reflect the influence of heat flow on silica precipitation. The $\delta^{18}O$ values range from 35.6‰ to 20.9‰. This accords to a temperature range from 11°C (24°C) to 86°C (102°C) depending on published equations. The calculated thermal gradients vary from 2.8 (3.9)°C/100m to 9.1 (14.5)°C/100m. In shallow subbottom-depths, far away from the basement temperatures, temperature gradients are in good agreement with those derived from the calcites. However, near the sediment/basement interface hydrothermally altered quartz reveal high mineral formation temperatures and steep thermal gradients possibly caused by unusual high heat flow during "hot times" of Atlantic Ocean basin formation.

FEATURES AND ORIGIN OF JURASSIC TO TERTIARY RADIOLARIAN CHERTS ASSOCIATED WITH OPHIOLITES IN SOUTHERN CENTRAL AMERICA

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The Nicoya Ophiolite Complex in southern Central America consists of tholeiitic basalts and volcanoclastic breccias formed during the Jurassic to Early Tertiary. The Lower Nicoya Complex is interpreted as oceanic crust accreted in a spreading ridge; the Upper Nicoya Complex consists of an oceanic intraplate subcomplex and a primitive island-arc subcomplex. Fine-grained sedimentary rocks, mostly "classical" reddish radiolarian cherts intercalated between the Lower and Upper Nicoya Complexes, make up 1-2% of the ophiolite sequence. Based on regional mapping, sedimentologic, petrographic, X-ray diffraction and geochemical analyses, the radiolarian cherts are interpreted to have been deposited on normal MORB of the Lower Nicoya Complex far below the CCD on the rugged floor of the eastern equatorial Paleo-Pacific Ocean. An oxic, low-energy, deep-sea basinal environment is deduced from the high purity of the biosiliceous rocks, scarcity of terrigenous detritus, relatively high hematite content, occurrence of early diagenetic manganese nodules and influence of low-concentration turbidity and/or bottom currents. The subsequent formation of the Upper Nicoya Complex resulted in strong deformation and thermal metamorphism of the radiolarites.

A thick, island-arc related, mostly clastic sedimentary suite of Campanian to Late Tertiary age overlies the Nicoya Ophiolite Complex. Intervals of grey, impure radiolarian cherts occur in the Lower Campanian and Paleocene/Eocene. They formed partly above the calcite lysocline to the CCD and partly below the CCD in morphologically variable, relatively quiet basins connected to the western Tethys with an episodic supply of island-arc debris by low-concentration turbidity currents.

LOWER CARBONIFEROUS CHERTS IN GERMANY AND THE PALEOCEANOGRAPHY OF THE UPPER PALEOZOIC PALEOTETHYS

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Lower Carboniferous cherts ("Kieselschiefer") in the Rhenohercynian zone of the central European Variscides have been studied in the field and by petrographic and geochemical methods. In contrast to the sedimentological and petrographical "monotony" generally attributed to these cherts, striking differences in thickness, organization and lateral development as well as lithology and petrography are observed. The actual mineralogy and some of the textural features do not represent the original sediments but were acquired during diagenesis and postdiagenic processes. Relict structures and reconstruction of the diagenic history give evidence of radiolaritic, spiculitic, pelitic, and volcaniclastic original sediments transformed into the actual fine-grained chert lithology by extensive silica mobilization, migration, redistribution, reprecipitation and replacement. Various bedding styles occur. Omnipresent lamination was caused by variable flow and depositional mechanisms and typical rhythmic bedding is probably due to fluctuating biogenic production and/or clastic dilution (orbital cycles). Bedding is partly produced or enhanced by post-depositional processes, especially by pressure solution. The cherts were deposited in the narrow, upper bathyal tropical Paleo-Tethys between Gondwana and Laurussia. Nutrient-rich westward currents from the Paleo-Pacific Ocean favoured a high radiolarian production; terrigenous clastic supply was extraordinarily low due to high sea level and a dry climate. The Variscan collision of Gondwana and Laurussia resulted in an increase of terrigenous input and a breakdown in oceanic circulation and thus terminated the siliceous sedimentation phase.

INTERANNUAL VARIABILITY OF PARTICULATE FLUXES TO THE ARABIAN DEEP SEA

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Since 1986 particulate fluxes have been continuously measured by moored time-series sediment traps at three locations in the western (16°20'N, 60°28'E), central (14°32'N, 64°47'E) and eastern (15°30'N, 68°45'E) Arabian Sea. Two traps were deployed at each location at depths of about 1000 m and 3000 m.

The seasonal flux pattern is controlled by the monsoons which occur twice a year: the SW monsoon between June and September, and the NE monsoon between December and March. During both monsoons higher particulate fluxes to the deep Arabian Sea are observed about 4 to 6 weeks after the onset of the monsoon-related increases in wind speed. Total fluxes measured for three years in the central and for four years in the western and eastern Arabian Sea reveal interannual variations by factors between 1.2 and 1.4 at the three locations.

Analyses of bulk component fluxes in conjunction with the available information on variations in monsoon intensity, wind speeds and sea-surface temperatures show large differences in processes controlling interannual variations between the three locations. Increase in fluxes with increasing monsoon intensity is observed in the central Arabian Sea, whereas neither monsoon intensity, nor surface cooling correlates with particulate fluxes in the eastern Arabian Sea. In the western Arabian Sea the intensity of surface cooling rather than monsoon strength determines the quantity of particles settling to the deep sea. These findings have important implications for the interpretation of the Pleistocene sedimentary record, when monsoon strength showed considerable variations between glacial and interglacial periods.

QUATERNARY CARBONATE PRESERVATION RECORD AT INTERMEDIATE WATER DEPTHS: ODP HOLES 817A and 818B, TOWNSVILLE TROUGH, NORTHEAST AUSTRALIA

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The Quaternary record of metastable carbonate preservation at intermediate water depths was determined from ODP Holes 818B (745 mbsl) and 817A (1015 mbsl) based on the downhole variations of (1) bank-derived fine aragonite and magnesian calcite content, and (2) the fragmentation of aragonitic pteropod tests. This data set was converted to time using an age/depth curve based on oxygen isotope stratigraphy and nanno/foram biostratigraphy.

Because these holes lie within the core of modern Antarctic Intermediate Water (AAIW), they are well-positioned to monitor past variations of its carbonate saturation state within the Townsville Trough. Our results show a general increase in carbonate preservation between 1.6 and 0.9 Ma, which ends during a brief dissolution interval from 0.9 to 0.86 Ma. This interval is followed by a sharp increase in preservation near 0.85 Ma, which is coincident with a major and permanent increase in the fine aragonite input to the slope environment. This marks the beginning of a period characterized by generally good preservation which extended from 0.85 to 0.41 Ma. The mid-Brunhes

dissolution interval is well-established from 0.41 to 0.36 Ma, and is followed during the last 0.35 M.y. by a general increase of carbonate preservation, mainly illustrated by an overall decrease in pteropod fragmentation. This "long-term" record of $CaCO_3$ preservation appears to be similar to carbonate preservation records from the deep Indian and eastern Equatorial Pacific Oceans, as well as to intermediate water records from sites near the Bahamas and the Maledives.

At the resolution of climatic stages, the carbonate preservation pattern during the last 0.35 m.y. shows generally good preservation during interglacial stages, whereas glacial stages display poor preservation. This carbonate preservation pattern is the opposite of the deep Pacific Ocean pattern and may indicate that, during the late Quaternary, glacial AAIW in the Townsville Trough was CO_2-rich while deep Pacific Ocean waters were CO_2-poor relative to interglacial periods.

EUSTASY, DETERMINED FROM SEQUENCE STRATIGRAPHY, LINKED TO THE PLIO-PLEISTOCENE OXYGEN ISOTOPE RECORD OF GLOBAL ICE VOLUME

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Both the eustatic curve, determined from seismic and well log sequence stratigraphy, and the oxygen isotope ($\delta^{18}O$) record, determined from deep-sea cores, are thought to reflect changes in global ice volume during the Plio-Pleistocene. However, in their original form, the two curves bear little resemblance. The poor correlation between these two records may be due to their differing frequency content. The Haq et al. (1988) sea-level curve shows third-order (0.5-3.0 M.y.) sea-level falls (sequence boundaries) at 4.2 Ma, 3.8 Ma, 3.0 Ma, 2.4 Ma, 1.6 Ma and 0.8 Ma. Recently, new sequence boundaries have been identified at 2.6 Ma, 1.9 Ma, 1.4 Ma (1.6 Ma of Haq et al., 1988), 1.1 Ma, and at 100 ky intervals from 700 ka to 400 ka (Wornardt and Vail, 1991). The isotope record indicates that high-amplitude, sea-level fluctuations of up to at least 120 meters have occurred at l00 ky intervals since approximately 600-700 ka. Prior to 700 ka, 41 ky low-amplitude Milankovitch obliquity cycles dominate the $\delta^{18}O$ record. To compare established $\delta^{18}O$ records to the Plio-Pleistocene eustatic curve derived from sequence stratigraphy, we applied a low-pass (l/250 ky - 1/125 k.y.) filter to stacked, orbitally-tuned isotope records from the North Atlantic Ocean (DSDP Site 607) and equatorial Pacific Ocean (ODP Site 677) (Raymo et al., l990). Stacking and filtering should remove local temperature affects and preserve the low-frequency ice volume signal. We selected a second low-pass (l/66 ky - 1/45 k.y.) filter to preserve the high amplitude 100 ky cycles present during the past 700 ky For the interval from 2.7 Ma to 5.3 Ma, we applied a low-pass (1/250 ky - 1/125 ky) filter to orbitally-tuned $\delta^{18}O$ data from Hole 625B (Gulf of Mexico) (Joyce et al., 1990). The generally good correlation between the composite low-frequency isotope record and the eustatic record of Wornardt and Vail (1991) suggests that: 1) fourth-order (100-500 ky) sea-level changes in the Vail curve are likely related to changes in ice volume, and 2) prior to ~700 ka, Plio-Pleistocene sea-level changes, at obliquity and precessional frequencies, may have been too small or too fast to develop "Vail sequences."

PALEOTEMPERATURE AND PRODUCTIVITY VARIATIONS IN THE NORWEGIAN-GREENLAND SEA DURING THE LAST 20 KYR: AN EAST-WEST TRANSECT

H. Haflidason (Geological Institute, Univ. of Bergen, Norway) and H.P. Sejrup

Based on planktic foraminiferal assemblages, total calcium carbonate analyses, AMS ^{14}C dates and tephra stratigraphy the paleotemperature and productivity variations are studied in three gravity cores from the Greenland Sea (70°38.9'N, 15°03.8'W), the Iceland Plateau (69°08'N, 13°07'W) and the Norwegian Sea (66°59'N, 06°12'W). The paleotemperature estimates were based on a regression analysis constructed from the planktic species *N. pachyderma* and *G. quinqueloba*.

In the core from the Norwegian Sea, close to the present center of the Norwegian Current, productivity was low, but stable between 20-16 ka BP. The same pattern is found within the Iceland Plateau. Both the SSST (5.9°C) and the WSST (0°C) were similar over the investigated area during the period, indicating a sea-ice cover at least through part of the year. The same temperature regime was found in the Greenland Sea, but the productivity there was 3-5 times higher than today. Relatively open-water conditions must have prevailed along the east coast of Greenland, suggesting a higher surface salinity than today and reduced fresh water input from the Arctic Ocean. From 16-13 ka productivity was low in the Norwegian-Greenland Sea and the temperature regime was similar to the earlier period, indicting a rather permanent ice cover. The relatively high abundance of subpolar fauna, similar to present values, over the Iceland Plateau indicates periods of open waters. In the period 13-9 ka the productivity remained low in the Norwegian-Greenland Sea. Subpolar species suggest a warm water influx, with peaks at 12.4 ka, 11.0 ka and 10.3 ka, indicating periods of unstable circulation with changing warm and cold water conditions (SSST varying from 6.0°-8.5°C and WSST from 0.0° -3.0°C). The surface waters of the Iceland Plateau and off East Greenland seem to have been dominated by more permanent ice cover and/or low salinity water than in the previous period. After 9 ka the productivity increased significantly and was high during the Holocene indicating that the present circulation pattern was established by this time. The peak productivity between 8.5 and 5.5 ka is also reflected in the sea-surface temperature which shows an increase of 1°C compared to the present values. This development is not found off East Greenland, where the subpolar species appear again at 6 ka and productivity reached present-day values.

SPATIAL AND TEMPORAL VARIABILITY OF LATE NEOGENE EQUATORIAL PACIFIC CARBONATE: ODP LEG 138

T. Hagelberg (College of Oceanography, Oregon State Univ., Corvallis, USA), N. Shackleton, L. Mayer, N. Pisias, A. Mix, and the ODP Leg 138 Shipboard Scientific Party

ODP Leg 138 has provided two transects of drilled sites across the eastern equatorial Pacific with continuous, high resolution (~ 1 kyr) temporal and spatial records of late Cenozoic climatic variability. GRAPE density variations (a carbonate proxy) across Sites 846-853 can be correlated across the sites, providing the potential to develop a high resolution, internally consistent chronologic framework (see Shackleton et al.). This temporal framework allows the exploration, at high resolution, of time- and space-varying patterns of

carbonate sedimentation. Where sedimentation rates are of sufficient resolution, spatial patterns of carbonate mass fluxes are examined.

Empirical Orthogonal Function (EOF) analysis extracts two independent modes of space and time covariability from the sites 846-853 GRAPE time series. The first mode, accounting for 50% of the total variability in the GRAPE data, has maximum weighting at the equator (Sites 847 and 849), and minimum weighting away from the equator, with all sites in phase. The second dominant mode, accounting for over 25% of the total variance, has minimum influence at equatorial sites 849 through 851 on the 110°W transect, and maximum influence at off-equator sites and on the eastern (95°W) transect. In addition, the off-equator sites (852, 853, and 848) are out of phase with the eastern transect sites (846 and 847) in the second EOF mode. The amplitude time series of the first dominant mode has variance concentrated at the orbital frequencies of 41 kyr, 23 kyr, and 19 kyr, and is highly coherent with insolation. The second mode is dominated by low frequency variance which is not coherent with insolation variations.

The spatial pattern of the first EOF suggests a productivity-related forcing mechanism of GRAPE (carbonate), possibly dilution by non-carbonate material during periods of high productivity. The spatial pattern is tightly coupled to the equator, with strong gradients away from the equator at every frequency. The second, low-frequency dominated EOF has a broader spatial scale (i.e., no strong gradients), possibly reflecting long term, basin-wide changes. The EOF analysis appears to resolve the basin-wide modes of orbitally-related and non-orbitally related space and time variability much better than analysis of individual sites.

REFINEMENT OF A HIGH-RESOLUTION, CONTINUOUS SEDIMENTARY SECTION FOR THE STUDY OF EQUATORIAL PACIFIC PALEOCEANOGRAPHY: ODP LEG 138

T. Hagelberg (College of Oceanography, Oregon State Univ., Corvallis, USA), A. Mix, N. Pisias, N. Shackleton, T. Janecek, and the ODP Leg 138 Shipboard Scientific Party

Ocean Drilling Program Leg 138 was designed to study the late Neogene paleoceanography of the equatorial Pacific at time scales of thousands to millions of years. Crucial to this objective was the acquisition of continuous, high resolution sedimentary records. To ensure that a continuous sedimentary sequence was sampled, each of the 11 drill sites was multiple APC cored. At each site, continuously-measured records of magnetic susceptibility, GRAPE density, and digital color reflectance (Mix, et al.) were used to monitor section recovery. At each site, these data were used to construct a composite depth section shipboard. This strategy verified recovery of a complete sequence with two or three offset piston cored holes. A single APC core with nominal 100% recovery only recovers about 90% of the sedimentary section. High quality continuous sections can be recovered with the extended core barrel (XCB) rotary system using adjacent overlapping holes.

Multiple measurements of GRAPE and other sedimentary parameters provides a means of constructing composite depth sections; however, it also provides multiple realizations of the same sedimentary process at each site. We have taken advantage of this opportunity during post-cruise processing of the GRAPE data. At each Leg 138 site, fine scale correlation (on the order of centimeters) of the GRAPE records was accomplished using the inverse correlation techniques of Martinson et al. (1982). After this refined correlation, the GRAPE records from each hole were "stacked" to provide a statistically robust, less noisy estimate of sediment bulk density, whose continuity can be documented in detail. The composite records were used to develop both an initial stratigraphic framework as well as a high resolution chronostratigraphic framework post-cruise (Shackleton et al.). The resulting stacked GRAPE time series have extremely high temporal resolution for most of the late Neogene. The resulting continuous framework provides a common depth scale for all holes at each site, facilitating comparison of high resolution proxy data between holes.

UPPER HOLOCENE MARINE SKAGERRAK (NE - NORTH SEA) DEPOSITS: SEDIMENTOLOGIC INVESTIGATIONS REGARDING THE PALEOCLIMATE OF THE PAST 1,000 YEARS

H.C. Hass (GEOMAR, Kiel, Germany)

3 kastencores, 1 piston core and 4 box cores taken with RVs "Planet" (1991) and "Poseidon" (1980) from the southern flank of the Skagerrak have been analyzed for high-resolution granulometry, coarse terrigenous and biogenic components, TC, TOC and $CaCO_3$ contents. Stable isotope ($\delta^{13}C$, $\delta^{18}O$) measurements and age determinations by means of ^{210}Pb and ^{226}Ra were carried out (in cooperation with Erlenkeuser, ^{226}Ra-Laboratory, Kiel). Until now at least one of the cores (15535-1) can be subdivided into 3 facial units:

Facies IIb (<1680 - 1725 AD): This unit is characterized by the conditions of the Little Ice Age climate deterioration. High sedimentation rates of more than 45 mm/a at the coring site are caused by increased deposition of material rich in organic content between 8 and 45 μm. The $\delta^{18}O$ curves indicate cooler temperatures than today up to ca. 1706 AD, followed by an interval of rapid warming until ca. 1725 AD.

Facies IIa (ca. 1725 - 1830 AD): This section is interpreted as the transitional stage between the Little Ice Age and the Modern Optimum. Several parameters point to a major environmental change: TOC values and suspension deposits decrease while bedload deposits increase accordingly, indicating higher current velocities and/or generally lower sediment load. $\delta^{18}O$ values point at a very slight but constant cooling trend until ca. 1830 to 1860 AD. Facies IIa seems to end with a short term influx of an oxygen-rich bottom water mass carrying less sediment at about 1840 AD.

Facies I (ca. 1840 - ca. 1955 AD): After the 1840 AD event, today's conditions (Modern Optimum) were established at the location. The $\delta^{18}O$ values indicate a slight warming trend during the 1840 to 1955 AD interval. According to distinct grain-size ratios and the shape of the TOC curve it can be concluded that bottom current velocities again slightly decreased. Although relevant parameters are subject to fluctuations, balanced conditions can be supposed. In the course of the upper 70 cm (ca. 1900 AD - present) it seems that man-made effects, such as pollution of water and atmosphere strongly affect the benthic foraminifera fauna. The $\delta^{18}O$ curves show a clear trend to lower values, and the benthic foraminifer *Bolivina* cf. *B. robusta* increases markedly while most of the other species decrease in number.

VANADIUM IN PLANKTONIC FORAMINIFERA AS A PALEOCEANOGRAPHIC TRACER OF BOTTOM-WATER REDOX CONDITIONS

D. Hastings (School of Oceanography, Univ. of Washington, Seattle, USA), S. Emerson, B. Nelson, J. Erez, and A. Mix

We are exploring the use of the V/Ca ratio in planktic foraminifera as a tracer of past V concentrations in the ocean. Pore water and sediment measurements indicate that the flux of V between sediments and sea water is sensitive to the redox chemistry of surface pore waters, which is determined mainly by the particulate rain rate of organic carbon and bottom water O_2 concentration. Anoxic sediments are a known sink for vanadium, while sediments overlain by low oxygen bottom water may be a major source of vanadium to the ocean. Assuming that other terms in the oceanic V cycle are constant over the past glacial cycle, changes in $(V)_{SW}$ should be a reflection of global changes in boundary conditions that control the redox state of the surface sediments.

Planktic and benthic foraminifera were cultured in the laboratory in sea-water solutions spiked with radioactive and natural vanadium. We have determined that incorporation of vanadium into the calcite test is directly proportional to sea-water V content. The distribution coefficient determined by these uptake experiments is 0.003 for *G. calida,* which is comparable to D = 0.006 for core top *G. tumida.*

Data from core-top samples from the Ontong Java Plateau in the Western Equatorial Pacific indicate that the V/Ca ratio of *G. tumida* decreases by a factor of three with increasing depth from 1600 to 4000 m. This is most likely a dissolution effect and a consequence of inhomogeneous distribution of vanadium in the test. We are presently searching for a species that has an homogeneous distribution of V, and cores where dissolution was not important so that the paleoceanographic signal can be obtained. The V/Ca profile obtained from an 18,000 yr coralline record off Barbados will be compared to the record from foraminiferal calcite.

TOWARDS MODELING THE PALEOCIRCULATION AND SEDIMENTATION OF THE NORTHERN NORTH ATLANTIC

B.J. Haupt (Special Research Project 313, Kiel, Germany), C. Schäfer-Neth, and K. Stattegger

Models: For studying the 3-dimensional circulation of the northern North Atlantic, the Modular Ocean Model (MOM), successor of the well-known Princeton Ocean General Circulation Model, is used. This model is based on the Primitive Equations including conservation of mass, heat, salt, and momentum. High resolution (1 degree zonal, 0.5 degrees meridional, 8 levels vertical) allows realistic representation of topography. Coupling to sedimentation is achieved by a model containing sediment transport equations which takes the velocity field produced by MOM as input. In this model, sediments can be supplied from the continental margins and the sea surface.

Sensitivity studies: First, the model's response to various modern forcing data has been tested: wind (Hellerman and Rosenstein, MPI Hamburg T21 model results), ice cover (CLIMAP), and thermohaline forcing (Levitus).

Selected time slices: Based on the available proxy data ($\delta^{18}O$, $\delta^{13}C$), the ocean's circulation has been modeled for selected Late Quaternary time slices, with emphasis on the Last Glacial Maximum (18,000 BP). Taking sedimentation rates from core data into account, sediment fluxes with resulting deposition/erosion patterns are computed to reconstruct the history of the sediment fill between time slices.

FLOW OF CURRENTS IN THE CRETACEOUS TETHYS

W.W. Hay (GEOMAR, Kiel, Germany), W.-Chr. Dullo, C.N. Wold, K.-A. Tröger, S. Voigt, R. Höfling, and G. Frank

We have plotted the occurrences of a variety of marine organisms on new global plate tectonic and paleogeographic reconstructions for the Santonian. A major difference compared to earlier reconstructions is that we have completely closed the Norwegian-Greenland Sea, which rotates Asia counterclockwise relative to western Europe and Greenland. Using the paleomagnetic reference frame of Harrison and Lindh (1982), we obtain a zonal boundary for the northern margin of the Tethys at 30° N. Unless the Hadley Cells were greatly restricted in the Cretaceous, this would place the entire Tethys under the influence of the easterly Trade Winds.

Two biogeographically important species of *Inoceramus* are restricted to the northern margin of the Tethys. True bioherms are also restricted to the northern margin and diversity of their faunas increases toward the Caribbean. The greatest diversity of reef organisms should be downstream, so that the increasing diversity from E to W implies westward flow of the waters along the northern margin of the Tethys. Although phosphorites do not occur in the Santonian, they were deposited in north Africa along the southern margin of the Tethys during the Campanian and Maastrichtian.

The distribution of the organisms is consistent with generally northwesterly Ekman flow of Tethyan waters beneath easterly Trade Winds. Upwelling would have occurred along the southern Tethyan margin and downwelling along the northern margin. On both margins there would have been a net westward zonal flow. Within the Tethys, the meridional flow would have always been to the north. Restriction of reefs to the northern margin may reflect either the difficulty of distribution of larvae upstream, or different hydrographic conditions along the southern margin.

PANGAEAN CLIMATOLOGY AND OCEANOGRAPHY

W.W. Hay (GEOMAR, Kiel, Germany; Dept. of Geological Sciences, CIRES and Museum, Univ of Colorado, Boulder, USA)

Geologic evidence indicates that Pangaea existed as a supercontinent from 270 Ma until 180 Ma. During its almost 100 million year existence it had a variety of climates. Its southern part, Gondwana, was glaciated from Late Mississippian until Middle Permian (330 Ma until 240 Ma). Polar ice disappeared and the continent reached a condition of extreme aridity during the Early Triassic (245Ma). At this time there is no clear record of the existence of an equatorial humid belt. During the later Triassic, the aridity of the continent decreased, and a "wet" episode occurred during the Late Triassic (Carnian, 225 Ma). The paleoceanographic record of Pangaea times is virtually unknown.

A variety of models have been used to simulate the climate of Pangaea. The interior of the continent was exceedingly arid. The seasonal temperature contrasts may have been 50°C. The temperature differences induced by

Milankovitch forcing were extreme. Strong monsoonal circulation was a characteristic of the atmosphere in Pangaean times.

A new General Circulation Model, GENESIS, has been used to simulate the climate of an Earth with realistic Triassic Pangaean geographies. The models indicate no ice cap on land and no permanent sea ice. The seasonal temperature variation is 50°C. The continent is very dry except for coastal areas and uplifts. Extreme seasonal monsoonal circulation produces strong westerly winds parallel to the entire coast of Gondwana and the east coast of Laurasia during June-August, inducing coastal upwelling. Permafrost occurs poleward of 50°. Topography strongly affects the monsoonal circulation causing major deviations of the winds suggested in earlier model runs with idealized geographies. Topography also plays a crucial role in concentrating rainfall in a few small areas.

LATE QUATERNARY STRATIGRAPHY IN THE FRAM STRAIT

D. Hebbeln (Universität Bremen, Germany) and G. Wefer

Stratigraphic analysis of sediments from the Fram Strait is mostly hindered by low abundances of foraminifera and other microfossils and by the occurrence of intervals totally barren of fossils. Therefore, most cores do not provide continuous records of oxygen isotope ratios, nor of any kind of species composition data.

Until now, only two Fram Strait cores with a continuous oxygen isotope record are published (Morris, 1988; Köhler and Spielhagen, 1990). Neither record shows the typical saw-tooth pattern known from lower latitudes and also found, e.g., in cores from the Norwegian-Greenland Sea. Due to the lack of this pattern, the interpretation of the oxygen isotope records is rather difficult. A higher time resolution than that provided by oxygen isotope stage boundaries seems more or less impossible.

Based on these two oxygen isotope records, a set of 14 sediment cores from two west-east transects across the Fram Strait was analyzed stratigraphically by correlating sedimentological, geochemical and micropaleontological data. All stage boundaries in the cores could be identified by this method. Age control for the correlation is partly given by high-resolution paleomagnetic analysis. A recently produced oxygen isotope curve for one of the cores confirmed the results of the correlation.

Sedimentation rates show a general increase from west to east, although highest rates were observed in the deepest parts of the Fram Strait. These areas, the Spitsbergen Fracture Zone, the Molloy Deep and the central rift valley of the Knipovich Ridge, clearly act as natural sediment traps with sedimentation rates >17 cm/kyr. Lowest sedimentation rates were found in the central southern Fram Strait (<2 cm/kyr). Intermediate rates were observed on the continental slope of Svalbard (3-7 cm/kyr). There is an apparent trend in almost all cores to higher sedimentation rates in glacial stages compared to interglacials.

LATE QUATERNARY PALEOCEANOGRAPHY IN THE FRAM STRAIT

D. Hebbeln (Universität Bremen, Germany) and G. Wefer

The recent oceanographic setting in the Fram Strait is mainly characterized by two dominant current systems. As a continuation of the North Atlantic Current, the West Spitsbergen Current (WSC) transports warm Atlantic Water northward through the eastern Fram Strait to the Arctic Ocean. The WSC is counteracted by the East Greenland Current (EGC) transporting cold Polar Water southward through the western Fram Strait. Due to the interaction of these water masses the ice cover in the Fram Strait is highly variable. Permanently and seasonally ice-covered areas are observed, as well as regions that are ice-free throughout the year.

Most important for the surface water oceanography of the Fram Strait during the Late Quaternary climatic cycles was the repeated shutdown of the WSC with enormous consequences for the climate in northern Europe and in the Arctic region. Tracing the WSC through time requires detailed knowledge about the existence and the extension of an ice cover in the Fram Strait and the adjacent seas.

Previous reconstructions for the last climatic cycle indicate that only during oxygen isotope stages 1, 5a and 5e warm Atlantic Water reached the Fram Strait. For colder periods, a permanent ice cover is assumed.
On the base of sedimentological, geochemical and micropaleontological data for a set of sediment cores from the Fram Strait it was possible to reconstruct five typical paleoceanographic scenarios and to trace them through time. The advection of Atlantic Water to the Fram Strait occurred mainly in interglacials, but also short events within glacial stages were observed. The EGC was always present after 300 kyr, showing a varying extension to the east. Between the two main currents, a cyclonic eddy was established for most periods. Events with a high input of ice-rafted material were confined to glacials, where the reconstruction of currents was possible by identifying differences in the composition of ice-rafted terrigenous organic matter.

SHORT-TERM ADVECTIONS OF ATLANTIC WATER TO THE FRAM STRAIT: MOISTURE SOURCE FOR THE BUILDUP OF THE LATE WEICHSELIAN BARENTS SEA ICE SHEET

D. Hebbeln (Universität Bremen, Germany)

Investigations of Barents Sea sediments indicate a relatively late buildup of the Late Weichselian Barents Sea ice sheet at approximately 23 ka (Elverhøi et al., 1992). For the buildup of such a large ice sheet a moisture source in its vicinity is required. Until now, most reconstructions of the paleoceanography of the Norwegian-Greenland Sea show permanent ice covered conditions for the entire Weichselian. Those conditions could hardly have provided the required moisture. New results from deep-sea sediment cores from the Fram Strait and a review of previously published data provide evidence for two short term advections of Atlantic Water as far north as 80°N. These events are indicated by micropaleontological and lithological parameters.

Occurrences of coccoliths and foraminifera indicate the advection of Atlantic Water and at least seasonal ice-free conditions. Further evidence for those conditions is given by the contemporary occurrence of the benthic foraminifera *Cibicides wuellerstorfi*. In this region, this species is often interpreted as an indicator for deep water formation, which is also tied to seasonal ice free surface waters.

The advection of Atlantic Water to the north can be traced also by the distribution of chalk fragments in the sediments. Chalk rocks occur only as far north as 59°N. Therefore, findings of chalk fragments in Norwegian Sea and Fram Strait sediments can be explained only by ice-rafting in a northward direction. In contrast to the Barents Sea ice sheet, the Fennoscandian ice sheet had a large extension throughout the Weichselian, allowing iceberg production in the source areas of the chalk fragments also prior to 23 ka.

The first advance of Atlantic Water occurred approximately 24 ka. Therefore, it seems likely that this advance is closely tied to the initial build-up of the Barents Sea ice sheet. The second advance took place at approximately 17 ka. This event is possibly a hint for a two-step glaciation of the Barents Sea indicating that the ice sheet reached its greatest extension not before 17 ka.

CORAL GROWTH IN RECENT REEFS OF THE RED SEA

G. Heiss (GEOMAR, Kiel, Germany) and W.-C. Dullo

Radiographs of coral slices of *Porites* show distinct patterns of high density/low density bands which each represent one year of coral growth. Most of the corals we have collected have an age of 4 to 9 years. According to Aharon (1991), *Porites* colonies reach their maximum growth rate at an age of approximately 10 years, indicating that the corals we sampled were still in an "adolescent" stage. We can also postulate that growth rates for older colonies are slightly higher than those outlined below.

The growth rates of corals have average values of 3-7 mm/yr; only few specimens of *Porites* gathered from the shore reef north of Queseir and Aqaba show a more rapid growth rate of 8-10 mm/yr. These values tend to be slightly lower than those published as growth rates for *Porites* spp. from the Pacific realm (between 7 and 14 mm/yr).

If we compare previously available values from samples taken from Aqaba, we find a great deal of evidence pointing at lower coral growth rates in the northern Red Sea than in the Pacific. This sparse amount of data also documents a relative slowing of growth rate with increasing depth. At this time we are preparing comparative studies on corals from the Comoro Islands (Indian Ocean). Our investigations at Aqaba in November 1991 and off the Egyptian coast in February 1992 provided us with more data to stabilize these trends.

Our investigations will be expanded to include some additional coral species. In addition we plan to try to quantify bio-erosion, as well as sediment export from the reef into the deep sea.

Objectives for future studies are:

- Extension of studies into the central Red Sea
- Seasonal changes in scleractinian biomineralization
- Comparison of phosphate affected and unaffected areas
- Measurement of (bio-) erosion rates
- Core sampling in the reef body to the Pleistocene basement
- Growth rate determination of other main reef-building corals
- Development of standardized research methods in order to compare the results on a global scale to the Caribbean and the Pacific
- Comparison of recent reefs and coral growth rates with fossil reef units formed during late Quaternary high stand sea-levels (e.g., Eemian, 125 ka)

Aharon, P. (1991): Recorders of reef environment histories: stable isotopes in corals, giant clams, and calcareous algae.- Coral reefs, 10/2: 71-90.

PALEOENVIRONMENT OF THE CENTRAL RED SEA DURINGTHE LAST 370,000 YEARS

C. Hemleben (Institut und Museum für Geologie und Paläontologie, Tübingen, Germany), A. Almogi-Labin, H. Erlenkeuser, D. Meischner, and R. Zahn

The cores cover a time span of ca. 370,000 y. In the case of KL11, the isotopic record has to be read as a salinity signal, rather than temperature or ice-volume signals, reflecting the special situation of this desert-enclosed marginal sea. The global sea-level changes affect the water exchange through the Strait of Bab el Mandeb. The unusal enrichment in ^{18}O mainly reflects the pumping efficiency of the high evaporation conditions coupled with the monsoon-driven surface waters (in- and outflow) between the Gulf of Aden and the Red Sea. The large-scale salinity fluctuations imposed on an already extreme marine environment causes pronounced variation in the calcareous plankton production, thus shaping the carbonate content curve. Milankovitch cyclicity (here the precession) in terms of the monsoon index (Rossignol-Strick, 1983) coincides with dominances of *Globigerinoides ruber* in the central Red Sea, indicating nutrient-rich, intermediate water driven by the SE Monsoon.

SURFACE-WATER REGIMES AND GLACIOMARINE PROCESSES IN THE NORWEGIAN-GREENLAND SEA I: MODERN REGIMES

R. Henrich (GEOMAR, Kiel, Germany), P. Goldschmidt, and T. Wagner

Based on the principle of actualism, a set of specific sedimentological and micropaleontological parameters has been used to identify the imprint of modern surface-water masses and glaciomarine processes in surface sediments. Combined with signals from biologic activity and geochemical processes at the benthic boundary, a general facies concept of pelagic and glaciomarine deposits from the Norwegian-Greenland Sea has been developed. Application of this concept in deep-sea sediment cores allows back-tracing of surface-water regimes and reconstruction of ice-drift patterns in the past.

SURFACE-WATER REGIMES AND GLACIOMARINE PROCESSES IN THE NORWEGIAN GREENLAND SEA II: THE PAST 450 KY

R. Henrich (GEOMAR, Kiel, Germany), P. Goldschmidt, and T. Wagner

Using the facies concept presented by Henrich et al. (this volume), surface-water regimes and glaciomarine processes were reconstructed for the past 450 ky. Circulation patterns in the Norwegian-Greenland Sea were quite variable, responding to glacial/interglacial climatic changes. Relatively warm conditions in a wide extension of Atlantic waters into the eastern sector is recorded during the isotopic events 11.1, 5.5.1, 5.1 and 1. Temperate interglacials with rather small intrusions of Atlantic waters are indicated for the isotopic events 9.3, 7.5, 7.3 - 7.1, 5.4 and 5.3. During the interglacial stages 7.4 and 5.2 a strong cooling

is recorded by a drastic decrease in pelagic carbonate fluxes and by a moderate IRD input in the eastern sector of the basin.

Various glacial circulation patterns are dicussed. Based on the sedimentological evidence, the authors favor a modified anti-estuarine circulation model. The major driving force would be strong catabatic winds at the boundaries of stable high pressures over the Scandinavian and the Greenland ice domes, which would be deflected by Coriolis force to the north on the eastern and to the south on the western side of the basin, resulting in a northward-bound Eastern Ice Drift Current and a southward-bound Western Ice Drift Current. In the center of the basin cyclonic gyres would connect the marginal ice-drift streams. Seasonal variations in sea-ice coverage and salt injection by a weak underflow of Atlantic waters in the southeastern-most areas could contribute to deep water formation. In detail, a more variable pattern is observed: very strong glaciations with peak supplies in IRD and almost basin-wide extension of glaciomarine diamictons (stages 12, 10 and 6); strong glaciations with high IRD input and diamictons restricted to the eastern and western basin sectors (stages 8, 4, 3, and 2); weak intrusions of Atlantic waters (events 8.6 - 8.5, 6.5 and 3.1).

LATE CRETACEOUS CALCAREOUS NANNOFOSSIL BIOCHRONOLOGY FROM THE ATLANTIC OCEAN.

A. Henriksson (Dept. of Paleontology, University of Uppsala, Sweden)

The rapidity of their evolution, wide geographic distribution and great abundance have made calcareous nannofossils one of the most used fossil groups for stratigraphic correlation of Mesozoic and Cenozoic marine sediments.

A quantitative study of calcareous nannofossils from four Deep Sea Drilling Project (DSDP) sites that span the late Cretaceous Atlantic Ocean from 37° N to 36° S has resulted in a dated subdivision for the latest approximately three million years of the Cretaceous. Six nannofossil events, three based on traditional markers and three new previously unused events have been calibrated to magnetostratigraphy. The ages of the stratigraphic markers are: First Occurrence (FO) of *Micula praemurus* 69.0 ± 0.2 Ma, FO of *Lithraphidites quadratus* 68.6 ± 0.1 Ma, Last Occurrence of *M. praemurus* 68.2 ± 0.3 Ma, FO of *Ceratolithoides kamptneri* 67.6 ± 0.2 Ma, and FO of *Micula murus* 67.2 ± 0.1 Ma. The use of *Nephrolithus frequens* as a marker was found here to be unreliable since its FO was diachronous. A refined uppermost Cretaceous calcareous nannofossil zonation from the middle Maastrichtian (upper part of *Arkhangelskiella cymbiformis* Zone) to the Cretaceous-Tertiary boundary is as follows: *Micula praemurus* Subzone, *Lithraphidites* quadratus Zone, *Cribrosphaerella ehrenbergii* Subzone, *Ceratolithoides kamptneri* Subzone, *Micula murus* Zone, and the *Micula prinsii* Zone.

^{230}THORIUM AND ^{10}BERYLLIUM STRATIGRAPHY OF TWO SEDIMENT CORES FROM THE ARCTIC SEA

G. Hentzschel (Heidelberger Akademie der Wissenschaften, Heidelberg, Germany), A. Eisenhauer, A. Mangini, R.F. Spielhagen, M. Suter, G. Bonani, and W. Wölfli

Two sediment cores from the Arctic Sea (core 21533 SL: 82°01.9'N 15°10.7'E, 2030 m water depth, 485 cm length, Yermak Plateau and core 21521 KAL: 82°56.5'N 32°5.2'E, 3752 m water depth, 467 cm length, Nansen Basin) were analyzed at high resolution for concentrations of the radionuclides ^{230}Th and ^{10}Be and for N, Fe and Al .

The cores were dated by ^{230}Th- and ^{10}Be-stratigraphy. For core 21533 the results were compared with a $\delta^{18}O$-profile.

The average sedimentation rate of core 21533 deduced from the ^{230}Th- and ^{10}Be-stratigraphies amounts to 3.1 cm/ky, which results in a bottom age of 147 ky correlating well with the oxygen isotope stratigraphy. The average sedimentation rate of core 21521, achieved only by ^{230}Th- and ^{10}Be-stratigraphy, is 3.4 cm/ky yielding a bottom age of 108 ky.

From the comparison of the ^{230}Th-, ^{10}Be- and $\delta^{18}O$-stratigraphies of core 21533 it can be shown that ^{230}Th- and ^{10}Be-stratigraphy can replace the $\delta^{18}O$-dating method in high latitudes.

We also can confirm that Fe- and Mn-oxihydroxides are the main carriers in the scavenging processes affecting ^{230}Th, and that aluminosilicates are the main carriers for ^{10}Be.

Together with the data of the cores 23235 (Fram Strait) and 364 (86°N) (Eisenhauer et al. 1990,91), our data yield a transect from North to South through the Arctic Ocean. It shows that climatic changes, current regime and oscillations of the southern boundary of the Arctic ice shield influence the fluxes of the elements in the sediments.

GLACIAL TO POST-GLACIAL CHANGES IN THE TROPICAL PLANKTONIC FORAMINIFERAL $\delta^{13}C$ RECORD: A PALEOPRODUCTIVITY RECONSTRUCTION

J.C. Herguera (Scripps Institution of Oceanography, UCSD, La Jolla, CA, USA) and W.H. Berger

We offer a new hypothesis on the succession of events that made last glacial $\delta^{13}C$ tropical planktonic values appear similar to the late Holocene ones, and led to the puzzling minimum during the last transition.

For the reconstruction of the equatorial surface $\delta^{13}C$ ecord, we chose four cores from the western equatorial Pacific ERDC core set, and located all of them well above the regional lysocline to avoid dissolution-related problems. We used the planktonic foraminifera *Globigerinoides sacculifer* because it is known to thrive best in surface, nutrient-depleted, warm waters, and because it seems to be the best recorder of warm, nutrient-depleted, surface mixed-layer, isotopic composition.

The reconstruction of an average Pacific Ocean $\delta^{13}C$ record, measured from shells of the benthic foraminifer *P. wüllerstorfi*, was derived from the average of two cores shallower than 2 km, thought to represent the mid-depth ^{12}C-depleted water masses, and two cores deeper than 2 km, thought to represent the ^{12}C-enriched glacial abyssal water masses.

We have already reported (Herguera, 1992; Herguera and Berger, 1991) how the primary productivity of the surface ocean is strongly correlated with the benthic foraminifera accumulation rates (BFAR) in the modern ocean. Here we apply this paleoproductivity reconstruction method to five cores, from western equatorial Pacific deep-sea sediment, spanning the last 18 ka.

The results offer some revealing insights into the surface water $\delta^{13}C$ record. Our evidence shows how a decrease in productivity during the late Glacial, coupled with the ocean's degassing to the biosphere during the transition, shape the surface-ocean planktonic carbon record during the glacial to post-glacial cycle.

FORAMINIFERAL AND ISOTOPIC EVIDENCE FOR ANOMALOUS VARIATION IN MONSOONAL INTENSITY AND PRODUCTIVITY IN THE ARABIAN SEA BETWEEN 35-50 kyr

J.O.R. Hermelin (Deep Sea Geology Division, Stockholm, Sweden) and G.B. Shimmield

A piston core, CD17-30, has been raised from a depth of 3,580 m immediately due east of the Owen Ridge (19°55.6'N, 61°42.9'E). A study of the benthic forminiferal assemblage has been undertaken and compared with the stable isotopic record recovered from both benthic (*U. peregrina*) and planktonic (*G. sacculifer*) foraminifera.

The $\delta^{18}O$ record of the planktonic species reveals noticeable excursions towards heavier ^{18}O values when compared to the benthic record and the SPECMAP stack. This is particularly obvious in isotopic Stage 3 between 35-50 kyr. A similar anomaly is seen in the $\delta^{18}O$ record of benthics at ODP Site 724 (Zahn and Pedersen, 1991; 593 m depth). Species diversity and abundance data on benthics from CD17-30 reveal that several species increase during colder glacial periods (stages 2 and 4) and, in particular, during the stage 3 cold 'event,' whereas others display an inverse distribution. From 19 key species, correspondence analysis allows us to determine that 52% of the total sample variation may be accounted for in the first three factors. This analysis allows the down-core distribution of the benthic foraminiferal populations to be analyzed, and indicates that one assemblage appears to vary on a precessional cycle, perhaps responding to monsoon-driven upwelling and associated food supply, while another assemblage is tied to the 100 kyr ice-volume cycle and may be responding to changes in AABW chemistry.

Paleoproductivity tracers, such as Ba, have a very similar distribution in both time and frequency domains. Planktonic foraminifera, such as *G. bulloides*, also display an obvious maxima in the stage 3 event which occurs at a time of reduced rate of amplitude change in both solar radiation and monsoon pressure index (Prell and Kutzbach, 1987).

Taking this evidence together points to a particular event of some 15 kyr duration during Stage 3 that resulted in cooler-than-normal surface waters, enhanced productivity and rapid settling of biogenic matter. The Holocene climatic optimum and associated productivity in the Arabian Sea appears to result from a different mechanism, most probably enhanced nutrient supply to the northern Indian Ocean.

GLOBAL OCEAN DISTRIBUTION OF DISSOLVED SILICATE IN NEAR-SURFACE WATERS AND ITS RELATIONSHIP TO PHOSPHATE DISTRIBUTION

U.C. Herzfeld (Scripps Institution of Oceanography, UCSD, La Jolla, CA, USA), J.L. Reid, and W. Berger

The silicate distribution traces diatom productivity, an important component of global ocean primary production. On a global scale, the spatial distribution pattern of silicate is similar to that of phosphate, which is highly correlated to primary productivity, but silicate has a much higher variability. We explore similarities and differences of silicate and phosphate distribution and their relevance for primary production.

In recent years, more silicate measurements have become available, which allows one to construct a global map of the silicate distribution, using geostatistical estimation. An algebraic algorithm is employed in a quantitative spatial comparison of silicate, phosphate and estimated ocean productivity.

Global maps of silicate and phosphate distribution (at the 100m level), and of the degree of their differences are presented and discussed. Implications of this approach for paleoceanography are attempted.

DIRECT CORRELATION OF SOUTHERN HEMISPHERE TERRESTRIAL AND MARINE PALEOCLIMATIC RECORDS FROM THE LAST THREE GLACIAL CYCLES: EVIDENCE FROM SITE 594 (45°31'S, 174°57'E)

L.E. Heusser (Lamont-Doherty Geological Observatory, Palisades, NY, USA) and G. van de Geer

Over the last ~350 kyr, changes in the composition of vegetation on New Zealand (inferred from pollen analysis of the upper 40 m of DSDP Site 594 at ~2.4 kyr sample intervals) reflect regional climatic variations which appear synchronous with implied variations in glacier fluctuation and in global climatostratigraphy described from sedimentary and oxygen isotope records from the same samples (Nelson et al., 1985). Pollen assemblages from isotope Stages 1, 5e, 7a, 7b, and 9 are composed of representatives of mixed conifer/broadleaf forests which vary in composition, suggesting major differences in precipitation and/or temperature in the last four interglacials. Glacial pollen assemblages, which imply the expansion of grassland and decline in rain forest components, show less variation and suggest comparatively dry, cool conditions on the east coast of South Island. The close correspondence between variations in the amplitude and timing of these records of forest development on New Zealand and oxygen isotope climatostratigraphy supports previous observations suggesting that late Quaternary southern and northern hemisphere climatic fluctuations are essentially synchronous.

DIACHRONEITY OF NEOGENE PLANKTIC FORAMINIFERA IN THE ATLANTIC OCEAN

H. Hilbrecht (Geological Institute, ETH Zentrum, Zürich, Switzerland)

We (Lazarus et al, this vol.; Spencer-Cervato et al., this vol.) extracted published bio- and magnetostratigraphic data and created new age-depth models based on age calibrations by Berggren et al. (1985). 23 Atlantic sites at 16 locations had reliable magnetochronologies and were chosen for a detailed diachroneity analysis. 11 first appearances (FAD) of planktic foraminifera are widely recognised in the Neogene.

Diachroneities range between a few 100 ka to several my, mostly between 1-5 my. Some pattern seems to exist in biogeographic histories. Species that appear first in the tropical or subtropical provinces appear later in the transitional zone and then spread towards lower latitudes in the eastern Atlantic upwelling province. Species that originate in the transitional zone appear in the eastern Atlantic first before they spread towards the subtropic and tropic

provinces. Time scales for migration in E-W and N-S directions of 1-10 Ma suggest gradual adaptation to laterally different environmental conditions even though passive drift of the planktic foraminifera would have allowed rapid dispersal in the Atlantic.

PLEISTOCENE CHRONOLOGY AND PALEOCEANOGRAPHY OF THE PLIO/PLEISTOCENE BOUNDARY STRATOTYPE AT VRICA

F.J. Hilgen (Institute of Earth Sciences, Univ. of Utrecht, The Netherlands) and L.J. Lourens

High-resolution proxy records of sea-surface temperature (SST) and productivity (SSP) are presented for the Mediterranean early Pleistocene. These records are based on the first two significant axes of principal component analysis applied to a quantitative planktonic foraminiferal record from the Plio/Pleistocene boundary stratotype section at Vrica (southern Italy).

In addition, a precise age model was established by the calibration of the Pleistocene sapropels in this section to the astronomical time series of precession. The proposed calibration implies that the small-scale sapropel cluster n-o-p does not correspond to a 100 kyr eccentricity maximum, as was expected on the basis of late Pleistocene phase relations between sapropel cycles and the orbital parameters. It reflects an interference pattern of precession and obliquity at the time that eccentricity reached minimum values in the 400 kyr cycle, around 1.6 Ma. As a consequence, the Pleistocene part of the Vrica section ranges from 1.36 to 1.81 Ma or, in terms of isotope stratigraphy, from stage 43 to 65.

Astronomical age calibration, using 4 kyr-lagged precessional ages for the sapropels, and subsequent spectral analysis yielded highly significant peaks in the precessional and obliquity frequency bands of the spectrum, indicating that variations in SST and SSP are controlled by these quasi-periodic variations in the Earth's orbit. Precession-related variations are sapropel-bound and reflect changes in regional climate and oceanographic conditions, whereas obliquity-related variations reflect glacial-integlacial alternations. The latter can be correlated perfectly to the standard isotope record of DSDP Site 607. Like in this northern Atlantic site, all glacial stages from 64 to 44 are marked by peak abundances of sinistrally coiled *neogloboquadrinids*. The succeeding absence interval in the Atlantic is also recorded in the upward extension of the Vrica section near Crotone. In this Crotone section, the base of isotopic stage 36 is probably reached.

Cross-spectral analysis revealed that astronomically-related frequency components in SST and SSP are strongly coherent with the orbital variations. Moreover, the 41 kyr components in SST and SSP, as shown by the phase spectra, lag obliquity by 10 kyr, i.e., comparable to the lag found for this component in the Late Pleistocene.

LATE NEOGENE CLIMATE CHANGE: A SOUTHERN OCEAN PERSPECTIVE

D. Hodell (Dept. of Geology, Univ.of Florida, Gainesville, U.S.A.)

ODP Site 704 contains a near-continuous stable isotopic record for the Plio-Pleistocene (4.8 Ma to present). During the early-to-mid Pliocene (~4.8 to 3.2 Ma), the amplitude of the $\delta^{18}O$ signal was ~0.5 ‰ and absolute values were less than those of the Holocene. These results indicate some warming and minor deglaciation of Antarctica, but are inconsistent with scenarios calling for major warming and deglaciation of the Antarctica ice-sheet. The climate system operated within relatively narrow limits during the Pliocene prior to ~3.2 Ma (i.e., ~0.5 ‰), and the Antarctic cryosphere probably did not fluctuate on a large scale until the Late Pliocene.

The late Gauss was the time of greatest change in Neogene climate in the northern antarctic and subantarctic regions. The mean and amplitude of the $\delta^{18}O$ signal increased abruptly at 2.7 Ma, and the greatest $\delta^{18}O$ values of the Gauss and Gilbert Chrons occurred at ~2.6 Ma, just below a hiatus that removed the interval from ~2.6 to 2.3 Ma in Site 704. During this climatic transition, surface waters cooled as the Polar Front Zone (PFZ) migrated north and ice volume increased on both Antarctica and Northern Hemisphere continents. At ~2.6 Ma, benthic $\delta^{13}C$ values decreased toward the Pacific, marking the onset of glacial suppression of NADW.

The early Matuyama Chron (~2.3 to 1.7 Ma) was marked by relatively warm climates except for strong glacial events associated with isotopic stages 82, 78, and 70. At 1.67 Ma (stage 65/64), surface waters cooled as the PFZ migrated equatorward and oscillated about a far northerly position between 1.67 and 1.5 Ma (stages 65 to 57). Beginning at ~1.42 Ma (stage 52), all parameters ($\delta^{18}O$, $\delta^{13}C$, %opal, %$CaCO_3$) in Hole 704 become highly correlated with each other and display a very strong 41-kyr cyclicity.

During the Late Pleistocene, oxygen isotopic stages 7, 9, and 11 were the warmest interglacial conditions in surface waters of the Southern Ocean, whereas the strongest glacial conditions occurred during stage 12. Comparisons of benthic carbon isotopic gradients reveal that production rates of NADW were strongest during stages 7, 9, and 11 and weakest during stage 12, supporting a link between the flux of NADW and paleoceanographic conditions in the Southern Ocean.

ORGANIC FACIES EVOLUTION OF NEOGENE AND QUATERNARY SEDIMENTS FROM THE NORWEGIAN SEA (ODP LEG 104/VØRING PLATEAU)

J. Hölemann (GEOMAR, Kiel, Germany), R. Henrich, and M. Wiesner

The quantity and the type of organic matter in sediments from the Vøring Plateau (Leg 104, Sites 642, 643, and 644) were studied in detail by Rock-Eval-pyrolysis and organic petrology.

During the Early Miocene the organic matter composition was changing from a terrestrial dominated assemblage with moderate to high accumulation rates of organic carbon (AR_{TOC}) to a more marine organic facies with a lower AR_{TOC}. This is caused by a decreasing input of terrestrial organic matter due to climatic changes on the nearby continent, or a successive sea level rise which would result in enhanced entrapment of organic matter on the continental shelves.

High AR_{TOC} and organic carbon contents of more than 5 wt.% (Site 642) are characteristic for the Lower Middle Miocene (15.5-14 Ma). The organic matter spectrum shows a high proportion of large organic particles of terrestrial origin, mainly oxidized plant fragments. It is not completely understood If this is related to sea-level and/or climatic changes or a high reworking of older sediments from the continental slope.

Although the Early and Lower Middle Miocene sediments show a high accumulation rate of biogenic opal, the organic matter related to the high opal-productivity is almost completely mineralized. The major autochthonous particles were dinoflagellate cysts and partly degraded fragments of algae.

Low AR_{TOC} and a predominance of autochthonous organic matter are diagnostic for the time period from 14 to 2.5 Ma. This is followed by a dramatic change of the organic facies at 2.5 Ma recorded at all three sites. At this time the first major glaciations on the Scandinavian continent caused an intensive glacial abrasion of outcropping Mesozoic organic-rich rocks that rimmed the Scandinavian continent at its eastern border. This thermally mature organic matter was redeposited in the Norwegian Sea by ice rafting and is generally found in large amounts in the glacial sediments younger than 2.5 Ma. Here, peak TOC values of 1-1.5 wt.% are almost exclusively made up by reworked organic particles (vitrinites, inertinites, and coal fragments).

PHYSICAL PROPERTIES OF SEDIMENTS FROM THE EQUATORIAL EAST PACIFIC (ODP LEG 138)

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The primary objective of ODP Leg 138 was to define the paleoceanographic evolution of the eastern equatorial Pacific during the last 12 million years. To address this objective, over 5500 m of core were recovered from 11 sites drilled along two north-south (9° W and 110°W) transects that crossed the complex oceanographic circulation system of the equatorial Pacific. One goal of the Leg 138 physical property program was to determine the impact of paleoceanographic changes to the physical properties of sediments.

The lithologies recovered during Leg 138 ranged from siliceous clays and carbonates through laminated diatomites and metalliferous sediments.

The downcore distribution of physical properties generally shows that two factors control physical property data. Gravitational compaction causes a reduction of water content and porosity. Due to consolidation processes, shear-strength, wet-bulk density, and thermal conductivity increase. Variations in lithology from calcareous to siliceous sediments result in an increase in water content and porosity, whereas wet-bulk densities and thermal conductivities decrease. Grain density, the "material constant", is lower for intervals rich in siliceous material. The lithologic variations recorded in all holes generally mask the effects of gravitational compaction.

SEQUENCING OF EVENTS IN THE NORTH PACIFIC WITH RESPECT TO CONTINENTAL DUST AVAILABILITY

S.A. Hovan (Dept. of Geological Sciences, Univ. of Michigan, Ann Arbor, USA), D.K. Rea, and N.G. Pisias

Core V21-146 provides a continuous record of northwest Pacific pelagic sedimentation spanning the past 530,000 years. Downcore variations of $\delta^{18}O$ from benthic foraminiferal calcite were correlated to the SPECMAP record to provide an age model for late Pleistocene paleoclimatic and paleoceanographic variation.

Eolian material was isolated using a series of chemical extractions and analyzed to determine mass flux and grain size data. The flux of eolian dust is a proxy measure of the source area aridity and correlates well to the loess-soil

stratigraphy in China. Dust fluxes range from 43 to 718 mg/(cm^2 kyr)$^{-1}$ and are greater by a factor of about 4 during glacial times. Cross-spectral analysis of the eolian flux and oxygen isotope records shows an in-phase and coherent relationship at each of the orbitally-related periodicities of 100, 41, and 19 kyr. The grain size of eolian material records the relative intensity of transporting winds and ranges from 8.4ϕ (2.9 μm) to 6.2ϕ (13.6 μm). A change in grain-size variability occurs about 300 ka such that the older portion is characterized by lower-frequency and higher-amplitude fluctuations than the younger portion. Power spectra for the eolian grain size record show dominant peaks at 100 and 50 kyr and a broad 25-35 kyr peak but coherency to the oxygen isotope curve at only the 100 and 33 kyr periodicities. The phase relationship for eccentricity between the eolian grain size and $\delta^{18}O$ records suggests that at the 100 kyr frequency the smallest grain sizes are associated with glacial conditions.

NEOGENE ATMOSPHERIC CIRCULATION INTENSITY AND CLIMATIC VARIABILITY RECORDED BY EOLIAN SEDIMENTS FROM LEG 138, EASTERN EQUATORIAL PACIFIC

S. A. Hovan (Dept. of Geological Sciences, Univ. of Michigan, Ann Arbor, USA)

Atmospheric circulation is an important aspect of the global climate system. Changes in the position and strength of major wind systems can have a major impact on climate and oceanic circulation. At present, hemispheric differences in the strength of atmospheric circulation causes a northward displacement in the Intertropical Convergence Zone (ITCZ) or the 'meteorologic equator'. Isolation and analysis of the eolian component in sediments collected during Leg 138 along a north-south transect near 110°W provide an opportunity to examine changes in the strength of atmospheric circulation (eolian grain sizes) for both the northern and southern trade winds throughout the Neogene and the effects these changes may have had on continental climates (eolian mass flux).

Eolian mass accumulation rates during the late Neogene vary between 5 and 40 mg/(cm^2 kyr)$^{-1}$. Sites presently located beneath the influence of northern hemisphere atmospheric circulation show a dramatic decrease in the flux of eolian dust associated with the onset of northern hemisphere glaciation at about 2.5 Ma. Eolian flux records from southern hemisphere locations show no apparent response to this event.

Temporal variations in the grain size of eolian material from the southern hemisphere show a slight coarsening of particles during the late Miocene from about 7.5 to 5.0 Ma. Interestingly, the southern hemisphere atmospheric circulation intensity record shows no apparent response to the Late Pliocene onset of northern hemisphere glaciation. Continuing work on samples from the northern sites will enable an investigation of changes in the intensity of northern trade-wind circulation during this time and allow a comparison between these wind systems and their relation to continental climates.

A MODEL STUDY OF THE GLACIAL OCEAN

S. Hovine (Univ. Catholique de Louvain, Institut d'Astronomie et de Géophysique, Louvain-la-Neuve, Belgium) and Th. Fichefet

A global ocean model based on primitive equations and zonally averaged over the main oceanic basins (Atlantic, Pacific and Indian) has been developed to investigate the global ocean circulation at the astronomical time scale. The steady-state reached under restoring boundary conditions to the observed present-day, sea-surface temperatures (SSTs) and salinities (SSSs) reproduces fairly well the conveyor belt, with deep water formed primarily in the North Atlantic at a rate of about 15 Sv ($1 Sv=10^6 m^3 s^{-1}$), from which a deep flow spreads into the Pacific and Indian basins, where it upwells. Upon switching to mixed boundary conditions, this circulation remains stable. To test the ability of the model to have more than one stable mode of operation, a standard deglaciation experiment is performed by applying in the North Atlantic a freshwater flux anomaly equivalent to the freshwater discharge corresponding to the complete melting of the North American ice sheet in 8,000 years. A few centuries after the beginning of the perturbation, the model simulates a complete reversal of the Atlantic thermohaline circulation, with deep water formed in the South Atlantic. When the anomalous flux is switched off, the conveyor belt recovers in about 2,000 years. A simulation of the ocean state at the Last Glacial Maximum is also conducted. In this experiment, the SSTs are related to the CLIMAP data, while the SSSs are restored, in the North Atlantic, to the Duplessy et al. (1991) reconstruction. In the South Atlantic, Pacific and Indian basins, hypothetical SSSs based on geological evidence are used. The simulated ocean circulation is discussed and carefully compared with the existing geological reconstructions. In addition, the predicted water-mass characteristics are examined in detail.

SOUTHERN OCEAN ORIGIN OF BISERIAL PLANKTONIC FORAMINIFERA (*CHILOGUEMBELINA* AND *ZEAUVIGERINA)* BELOW THE CRETACEOUS/TERTIARY BOUNDARY

B. Huber (Dept. of Paleobiology, Smithsonian Institution, Washington, D.C., USA) and A. Boersma

One lineage of typically Tertiary chiloguembelinids and zeauvigerinids (biserial planktonic foraminifera) originated in the Late Cretaceous of the Southern Ocean (Huber, 1990). Four species and two genera have now been recognized by scanning photography and X-ray analysis from the Late Maastrichtian *Abathomphalus mayaroensis* Zone at ODP Sites 690, 738, and 750 where they originated and were most abundant. First occurrences, several cores below the boundary zone sediments which are mixed or interrupted by chert deposition, cannot be attributed to downcore mixing or contamination in drilling paste.

In the Late Cretaceous there is biogeographic provincialization of these species; elongate species and forms tending to uniseriality predominate in the Indian Ocean Antarctic (Hole 738C) and over Kerguelen Plateau (Hole 750A), while the only form found consistently in the Weddell Sea (Hole 690C) is the short, oblate, temperate species, *Chiloguembelina crinita* (GLAESSNER). This species also occurs in low abundances at the Indian Ocean sites.

Across the Cretaceous/Tertiary boundary 3 of the 4 species survive and extend as far equatorward as the Angola Basin (Sites 527, 528). In the earliest

Tertiary a second chiloguembelinid lineage derives from the guembelitrids and appears simultaneously with the Cretaceous derivatives in Zone P alpha. By Zone P1 the three species are found throughout the Southern Ocean and Atlantic subantarctic from the Falkland to Agulhas Plateaus (Sites 689, 690, 750, 738, 700, and 702). The two elongate Cretaceous derivative chiloguembelinids disappear in Zone P1b, while the short, oblate species remains concentrated in the Southern Ocean until the Late Paleocene when it becomes cosmopolitan.

PALEOCEANOGRAPHY OF THE NORTHEAST AUSTRALIAN MARGIN: THE EFFECTS OF CHANGING CLIMATIC AND OCEANOGRAPHIC CONDITIONS ON CARBONATE SEDIMENTATION

A.R. Isern (Geological Institute, Swiss Federal Institute of Technology, Zürich, Switzerland), J.A. McKenzie, and Th. Fichefet

One of the major goals of Leg 133 was to study the temporal and spatial evolution of the Queensland Plateau. During the Middle Miocene, the plateau was covered by an extensive tropical reef complex. In the Late Miocene, a decrease in platform-derived sediment indicates back-stepping of the reef with a subsequent drowning of the carbonate banks. Data indicate that changes in surface water temperature, water mass circulation, and variations in productivity, combined with subsidence, caused the demise of reefs on the plateau.

Samples from ODP Sites 811 and 817, and DSDP Site 209, located on the deepwater slopes of the Queensland Plateau, were analyzed for $\delta^{18}O$ and $\delta^{13}C$ values in both planktonic (*Globogerinoides ruber*) and benthic (*Cibicidoides* spp.) foraminifers. These data were used to assess vertical and latitudinal temperature gradients and nutrient variations proximal to the Queensland Plateau and to determine how these factors affected the growth and demise of this carbonate platform.

Results show that surface water temperatures in the western Coral Sea were cooler during the late Miocene and early Pliocene, and were below that needed for productive reef growth (16-19°C). These surface waters were, undoubtedly, cooler than in the middle Miocene, as the widespread tropical reef complexes present at that time could not have flourished. Temperate-water carbonate facies recovered on the upper slopes also confirm lower surface water temperatures in the late Miocene. Carbon isotope results indicate that there was a possible increase in surface-water productivity in the late Miocene, concurrent with the temperature decrease. We propose that decreased surface water temperatures and increased nutrient concentrations placed sufficient stress on reef growth to limit net production. Warmer surface water temperatures, approaching modern values (~24°C), returned in the late Pliocene. This warming may have been a significant factor facilitating the appearance of the Great Barrier Reef in the Pleistocene.

QUANTITATIVE FAUNAL EVIDENCE OF PLIOCENE HIGH-RESOLUTION, DEEP CIRCULATION FLUCTUATIONS IN THE NORTH ATLANTIC

S.E. Ishman (U.S. Geological Survey, Reston, USA) and T.M. Cronin

Benthic foraminifers and ostracodes have been studied throughout the interval from about 3.2 to 2.8 Ma from North Atlantic Deep Sea Drilling Project holes 607 (41°00.07'N; 32°57.44'W) and 610A (53°13.29'N; 18°53.21'W). The objective of this study was to identify high-resolution benthic faunal changes, using two independent faunal groups, and relate these fluctuations to changes in deep Atlantic circulation. Results of qualitative and quantitative analyses of the faunal data show significant biotic events throughout the middle Pliocene. Variations in the abundance of the ostracode taxa *Krithe*, *Henryhowella*, *Poseidonamicus*, *Bosquetina* and *Echinocythereis*, and benthic foraminifers *Globocassidulina subglobosa*, *Epistominella exigua*, *Fontbotia wuellerstorfi*, *Oridorsalis umbonatus*, *Nutallides umbonifera* and *Uvigerina peregrina* characterize the changes in deep water circulation associated with the influence of North East Atlantic Deep Water (NEADW), North Atlantic Deep Water (NADW), and Antarctic Bottom Water (AABW).

It can be concluded from the data presented that: 1) ostracode and benthic foraminifer assemblage data are effective deep water mass paleoceanographic indicators for the Pliocene, 2) the paleoceanographic fluctuations identified at Holes 607 and 610A occur at approximately 41 kyr cycles, and 3) the frequency of these paleoceanographic events makes them independent of northern hemisphere glacial conditions, thus suggesting an alternative climatic forcing.

EVIDENCE TOWARD A PRE-GLACIAL COUPLED SEA SURFACE-DEEP CIRCULATION RESPONSE MODEL: NORTH ATLANTIC MIDDLE TO LATE PLIOCENE

S.E. Ishman (U.S. Geological Survey, Reston, VA, USA) and H.J. Dowsett

Deep Sea Drilling Project Holes in the North Atlantic along a latitudinal transect from the equatorial region to ~56° N in the 2,300- to 3,000-meter depth range were selected for a high-resolution study of coupled surface and deep ocean response to climate change. Magnetostratigraphic and biostratigraphic data for the cores selected provide precise age controls for the evaluation of incremental (10 kyr) changes in sea surface temperatures (SST) and deep North Atlantic circulation patterns between 4.0 and 2.2 Ma.

Planktonic-foraminifer-based factor-analytic transfer functions provided estimates of SST, and oxygen isotopic data from paired samples provided tests of the estimated temperature gradients between localities. Changes in deep North Atlantic circulation were evaluated on the basis of quantitative analysis of benthic foraminifer assemblage data and $\delta^{18}O$ and $\delta^{13}C$ isotopic data. These data were used to determine changes in source area (North Atlantic Deep Water (NADW) or Antarctic Bottom Water) and (or) in the components of NADW that were present (Upper or Lower NADW). These paired paleoceanographic sea surface and deep circulation interpretations over a 1.8 my interval form the basis for a coupled sea surface-deep circulation response model for the Pliocene North Atlantic Ocean.

NEOGENE-QUATERNARY CLIMATIC ZONATION OF THE WORLD OCEAN

E.V. Ivanova (P.P. Shirshov Institute of Oceanology, Academy of Sciences, Moscow, Russia), N.S. Oskina, and N.S. Blyum

Climatic zonation of the World Ocean was reconstructed for nine Neogene-Quaternary time intervals based on planktic forams. Comparing these schemes the migration of climatic zones was traced.

During the Neogene, subtropical bipolar zones shifted equatorward from the 30-60 th latitudes, replaced by a temperate and subpolar one due to progressive cooling during the Neogene. At low latitudes there were warm periods at the end of the Early Miocene, the end of the Miocene, Pliocene and the Late Pliocene; equatorial and equatorial-tropical zones widened. The last Interglacial was cooler than Neogene warmings, equatorial-tropical and tropical zones occupied low latitudes. The coolings at the end of the Middle Miocene and Middle Pliocene led to migration of the tropical zone to low latitudes while equatorial zones almost disappeared. At the last glacial maximum, the coldest among the time intervals studied, low latitudes were occupied by tropical and subtropical zones. During the Neogene-Quaternary the World Ocean climate became more contrast, pole to equator SST-gradients increased and surface circulation intensified.

EVOLUTION OF CLIMATE IN THE INDIAN OCEAN DURING THE NEOGENE

E.V.Ivanova (P.P. Shirshov Institute of Oceanology, Academy of Sciences, Moscow, Russia)

Comparing the distribution of planktic foraminiferal assemblages for seven Neogene time intervals, the migration of climatic zones was reconstructed. The climatic trends were different at low and high latitudes of the Indian Ocean. At high latitudes the climate progressively cooled during the Neogene and cold-water foraminiferal zones shifted equatorward except for the Early Pliocene. While at the beginning of the Miocene, the 50-60th latitudes were occupied by a rather warm zone comparable to modern subtropical, at the end of the Early Miocene, the temperate zone appeared here and the "subtropical" zone moved northward. The subpolar zone was recognized at 60th latitudes in the Latest Miocene. The cooling trend continued during the Pliocene. At low latitudes there were climatic oscillations with the warmest conditions at the end of the Early Miocene. During warmings, equatorial zones extended and topical-subtropical zones between the equatorial and temperate zones narrowed. During coolings, tropical-subtropical zones migrated several degrees northward and the warmest equatorial zone almost disappeared.

FRESHWATER DIATOMS AND PHYTOLITHS AS SIGNALS OF CONTINENTAL ARIDITY

J.H.F. Jansen (Netherlands Institute for Sea Research, Texel, Netherlands), E.M. Pokras, L.H. Burckle, and B. Stabell

Two types of siliceous microfossils in marine sediments are of terrigenous origin: freshwater diatoms and opal phytoliths. Phytoliths are siliceous clasts from leaves of vascular plants, mainly grasses. Most published studies attribute the presence of opal phytoliths and freshwater diatoms to predominant wind transport. These studies, however, are from the central Atlantic off northwest Africa where a major fluvial contribution is excluded because of the prevailing wind pattern and the presence of the Sahara. Nevertheless, large numbers of freshwater diatoms occur in sediments of the Guinea Basin near the Niger River mouth, which demonstrates that a fluvial contribution may not be ignored.

The distribution of the freshwater diatoms and opal phytoliths in surface sediments of the Zaire fan region point to two different terrigenous sources. The freshwater diatoms show large accumulation rates near the Zaire River mouth, which indicates that they originated from the drainage area of the Zaire River. The accumulation rates of the phytoliths have two concentrations, one in front of the Zaire River mouth and one more to the south. Apparently, the phytoliths also have a southern source, most probably the Kalahari in southern Africa, from which the southeast trade winds carry them to the fan region.

It can be easily understood why phytoliths are more susceptible to eolian transport and freshwater diatoms are more readily supplied by rivers. Phytoliths (Ph) occur on land, while freshwater diatoms (FD) are found in swamps, lakes, rivers and, less frequently, moist soils.

We have introduced the PhFD index, Ph/(Ph+FD), as a signal of the contribution of wind versus fluvial supply. The index appears to match the history of aridity in equatorial Africa during the last 30,000 years. This allows us, for the (hemi)pelagic sediments of the Zaire fan, to apply the PhFD index as an index of paleoaridity in equatorial Africa. In this study we test whether this is also true for the sediments off NW Africa. If so, we believe that the PhFD index can be used as a marine proxy of aridity on the adjacent continent.

CORTEX, AN XRF-SCANNER FOR CHEMICAL ANALYSES OF SEDIMENT CORES

J.H.F. Jansen (Netherlands Institute for Sea Research, Texel, The Netherlands), S.J. van der Gaast, B. Koster, and A.Vaars

The CORTEX (Corescanner Texel) is a computer-controlled instrument for the measurement of chlorine and elements of higher atomic number in piston cores, box cores and other types of samples with X-ray fluorescence (XRF).

The CORTEX offers the opportunity to get a good impression of the chemical composition of the solid phase already on board ship within half an hour after the opening of a core section. Then, the coring and chemical subsampling program can be adapted if necessary. In hemipelagic sediments, the Ca radiation may provide a very detailed calcium carbonate stratigraphy.

The CORTEX is able to do rapid measurements at small intervals. This implies that uncommon features will not easily escape from observation. Any desired step size can be ordered. A measurement takes only one minute, so a 1 m long core section is scanned with 5 cm steps in 20 minutes.

At present, the results are only qualitative; however, we verified the data with atomic absorption analyses. The results are very promising, and we believe that it will become possible to obtain semi-quantitative data for at least the most important chemical elements.

The CORTEX was designed and built at NIOZ and subsidized by the Netherlands Marine Research Foundation NWO/SOZ. It is equipped with a KEVEX PXS-4 X-ray tube and energy dispersive PSI-detector. The latter will be replaced by a newly developed KEVEX detector, which will allow to measure also Al and Si and to do a complete chemical analysis.

ONSET OF GLACIATIONS IN THE NORTHERN HEMISPHERE: STEPS ON A COOLING TREND

E. Jansen (Department of Geology, Univ. of Bergen, Norway)

Cold environments developed in the Norwegian Sea at least since the middle-late Miocene boundary. Glacial activity in the region can be documented since about 8.5 Ma, and was intensified in the Messinian which also marks a general cooling of surface and deep water environments at high northern latitudes. The major onset of large scale glaciation and spread of glaciers to sub-Arctic regions happened at about 2.7 Ma, however, identifying the onset of repeated strong glacial cyclicity in northern Europe. Glaciations further intensified at 1 Ma and at the same time enhanced meridional circulation developed during interglacials. The 2.7 Ma intensification is marked as a strong IRD-event, but happened within a clear cooling trend which started as early as 3.5 Ma. After 3 Ma strong high latitude forcing of climate and ocean variability developed: stronger glacials started to suppress NADW production and a strong obliquity element appeared in global ice-volume records, reflecting increased climate sensitivity of high-latitude regions.

ESTIMATED CO_2 LEVELS FROM PHOTOSYNTHETIC ^{13}C FRACTIONATION IN THE CENTRAL EQUATORIAL PACIFIC OVER THE LAST 255,000 YEARS

J.P. Jasper (Indiana Univ., Bloomington, USA), F.G. Prahl, A.C. Mix, and J.M. Hayes

A $\delta^{13}C$-based record of CO_2 levels was generated from a central equatorial Pacific sediment core (0-255 ka) using reconstructed histories of the $\delta^{13}C$ of Prymnesiophyte phytoplanktonic biomass and of CO_2 (aq). The biomass $\delta^{13}C$ record was generated from the $\delta^{13}C$ of a C_{37} alkadienones (measured by isotope ratio monitoring-gas chromatography/mass spectrometry) exclusive to the Prymnesiophyceae, algae which apparently grow at ~60-80 m. The $\delta^{13}C$ of CO_2 (aq) was reconstructed from the $\delta^{13}C$ of *N. dutertrei* which apparently calcifies at 70-90 m. Concentrations of CO_2 (aq) were estimated from the ε_p record, using an ε_p *vs* [CO_2 (aq)] calibration based on results from a Gulf of Mexico sediment core and from the Vostok ice core (VIC); equilibrium pCO_2 levels were calculated using Henry's Law. There is a general correspondence between variations *C. wuellerstorfi* $\delta^{18}O$ and reconstructed pCO_2, with high interglacial values and low glacial values.

MANOP Site C pCO_2 levels were generally higher than VIC levels in glacial stages and lower in interglacial stages. We infer that the alkenones and *N. dutertrei* tests were biosynthesized in the subsurface eutrophic layer (SEL), not in the upper oligotrophic (mixed) layer. This ε_p-based record of [CO_2 (aq)] represents the sum of processes bearing on CO_2 (aq) in the SEL: upwelling, biosynthetic fixation, and net particulate organic carbon (POC) oxidation. While calculations of contemporary surface-water $DpCO_2$ indicate a strong CO_2 source from equatorial Pacific surface waters, the present reconstructed pCO_2 record is one of subsurface waters which are not in direct communication with the atmosphere. Amplitude modulation of the pCO_2 record in the SEL (208-260 matm) relative to the ice core record (~190-280 matm) is consistent with (1) climatically-varying [CO_2 (aq)] caused by the changing ratio of CO_2 to nutrient inputs (with upwelling of waters bearing higher CO_2/nutrient ratios in glacial

stages than in interglacial stages) and POC degradation, (2) bioturbation of the record, and (3) climatically varying eolian influx of iron.

HYDRODYNAMIC CONTROLS OF ANOXIA IN CONTINENTAL INTERIOR SEAWAYS

P.W. Jewell (Dept. of Geology and Geophysics, Univ. of Utah, USA)

Continental interior seaways of the Mesozoic represent a unique geologic environment with no modern analogs. Research over the past decades has established that the Cretaceous Interior Seaway of North America was characterized by a density stratified water column which underwent periodic episodes of bottom water anoxia. General circulation models of the Cretaceous and sedimentological studies suggest that large storms were a fundamental part of the seaway environment. In modern shallow marine settings, high wind shear stresses tend to homogenize water column density and oxygen concentrations. The relationship between density stratification, water column anoxia, and the fluid shear stresses associated with storms has been studied with a mixed-layer, turbulence closure model coupled to simple biogeochemical models. A similar hybrid model has been used successfully by the author to study anoxia in modern lakes. Judicious use of the model allows constraints to be placed on depth, vertical density stratification, and the strength of storms which may have occurred during various transgressive and regressive stages of the Cretaceous North American seaway. Work is currently underway to construct a functional, 3-dimensional mesoscale model which should allow areal distribution of surface productivity, oxygen levels, and nutrient concentrations within the seaway to be established.

NEW INTERPRETATION POSSIBILITIES OF PAST OCEAN CIRCULATION AND CHEMISTRY ON THE COMBINED USE OF $\delta^{18}O$ AND $\delta^{13}C$ MEASURED ON PLANKTONIC FORAMINIFERS

T. Johannessen (Dept. of Geology, Univ. of Bergen, Norway), E. Jansen, and A.C. Ravelo

70 box-core samples from Greenland, Iceland and Norwegian (GIN) Seas, that cross important oceanographic fronts and water masses, have been used to evaluate equilibrium-disequilibrium, depth habitat, seasonality and the ability to simulate changes in ocean chemistry. The samples are mainly concentrated along an E-W transect across the Iceland Sea to the coast of Norway.

Results from a comparison of $\delta^{18}O$ predicted for present ocean with measured in foraminifers, shows that all species calcify their shells in disequilibrium. *Neogloboquadrina pachyderma* sinistral and dextral and *Globigerina quinqueloba* seem to calcify their shells in disequlibrium with 0.45‰ and 0.28‰ for *Globigerina bulloides*.

Strong gradients in $\delta^{13}C$ are developed for all species along the transect. The gradients seems to be related to the transition between the Polar to the Arctic water (Polar front) and to the transition between the Arctic into the North Atlantic Water (Arctic front). Enhanced $\delta^{13}C$ is measured related to the Arctic water in the Iceland Sea. Similar trends are observed in the phosphate normalized $\delta^{13}C$ of ΣCO_2, indicating a decoupling between phosphate and the $\delta^{13}C$ record.

A shallow position for calcification of foraminifer shells is needed to be able to explain the combined trend in the two proxies. In general, both parameters simulate the general ocean circulation in the GIN-Seas well, and can be used to reconstruct ocean circulation and water masses in past ocean.

THE PALEOECOLOGY AND PALEOCEANOGRAPHY OF *FLORISPHERA PROFUNDA* IN LATE QUATERNARY SEDIMENTS

R.W. Jordan (Institute of Oceanographic Sciences, Deacon Lab, Wormley, Surrey, UK), P.P.E. Weaver, and N.J. Shackleton

The coccolithophorid *Florisphaera profunda* is a low-latitude species inhabiting the deep photic zone (100-200m). Previous studies have proposed that its high relative abundance in surface sediments is indicative of a deep nutricline, and can be closely correlated to the SST as derived from planktic foraminifera data. A number of cores from both upwelling and open ocean locations within the Atlantic and Pacific Oceans have been analyzed. The abundance of *F. profunda* from these cores has shown that it is dominant in the open ocean sites and are in upwelling regions. Downcore variations in abundance at these open ocean sites may indicate periods of upwelling influence or seasonality involving the breakdown of thermocline. The absence of rarity of *F. profunda* in upwelling regions and in areas outside the low latitudes is presumed to be due to its ecological preferences for a stable permanent thermocline, low light levels and high nutrient concentrations. The preliminary data presented here would appear to support this hypothesis.

ATMOSPHERIC FORCING ON SEA SURFACE WATER

A. Juillet-Leclerc (Centre des Faibles Radioactivités, CNRS/CEA, Gif/Yvette, France), L.D. Labeyrie, and J. Jouzel

Evaporation (E), precipitation (P) are parameters calculated by GCM models. Isotopic cycles for oxygen have been also introduced in some models (δE: isotopic composition of evaporated water; δP: isotopic composition of precipitation). The comparison, for modern time, of the model estimates (E, P, δE and δP) and measured values, shows good agreement. A simple relationship between these atmospheric parameters and the isotopic composition of sea surface water from GEOSECS measurements has been established and tested. The statistical relationship deduced from this comparison gives a good correlation coefficient. The $\delta^{18}O$ of sea surface water is strongly dependent of the atmospheric parameters. If we assume that the atmospheric forcing was similar during the Last Glacial Maximum (LGM), taking into account of the global effect of ice storage, it is possible to use the same relationship in order to calculate sea surface water isotopic composition.

The comparison of this reconstitution and estimation from isotopic composition of foraminifera carbonate and temperature deduced from CLIMAP, shows the validity of such model reconstitution.

LAMINATED GLACIAL SEDIMENT HORIZONS IN THE NORTH ATLANTIC (MAURY CHANNEL, 3300M WATER DEPTH)

S.J.A. Jung (Geologisch-Paläontologisches Institut, Kiel, Germany), H. Erlenkeuser, A. Rosell, and M. Sarnthein

Sediments in the NE Atlantic are crucial for reconstructing past changes in the surface and deep water circulation between the North Atlantic and the Norwegian-Greenland Sea especially, the variations of the North Atlantic Drift and the Norwegian overflow water, i.e., the source of the North Atlantic Deep Water.

Sediment core 17049 was retrieved from 3331m on the Hatton Sediment drift at the southeastern Maury Channel, which today forms under the control of bottom currents of southern (Antarctic) origin. Oxygen isotope stratigraphy shows that in this core, peak and early glacial stages 8.4, 6.4 , 3/2 and the Younger Dryas are marked by an up to 30 cm thick laminated yellowish-gray and dark olive grey foram free mud. These are the first laminated sediments ever described from the deep northern Atlantic. Interesting to note that the concentrations of organic carbon in the dark laminae are lower than 0.1%, suggesting very low ocean productivity at that time. This is also supported by the high epibenthic $\delta^{13}C$ values at the top and the base of each laminea horizon. Based on Uk(37)- values, sea surface temperatures reached an absolute minimum lower than 8-10° C.

By now the laminated intervals are difficult to interpret since they were neither controlled by excessive carbon fluxes nor by unusually low oxygen content of the bottom water. A drastic lack of nutrients and strong remineralization are discussed as the possible origin.

VARIATIONS OF ^{18}O ISOTOPE AND CARBONATE CONTENT IN THE GREENLAND BASIN SEDIMENTS

B. Jünger (GEOMAR, Germany) and H. Erlenkeuser

On two cores from the southern central Greenland Basin carbonate content and planktic oxygen isotope ratios have been measured for closer information on paleoceanography in this area of the Norwegian-Greenland Sea. The sediments record the last 340,000 years.

The generally low carbonate content of less than 20% in both cores reveals the dominance of the inflow of the cold polar waters to the Greenland Sea. The same is shown by the $\delta^{18}O$ profiles. There are no prominent (light isotope) peaks indicating advection of warm Atlantic waters. In general, the oxygen isotope shift between interglacials (stage 9, 7, 5) including stage 3 and glacial stages (2, 4, 6) is small, and just reflects the ice effect or is even less.

Pronounced light $\delta^{18}O$ signals are occasionally shown other than in interglacials, e.g., in stage 3.3, at the stage boundary 4/3, and indicate the impact of meltwater episodes. Isotope stages 7.5 and 5.5 have nearly the same $\delta^{18}O$ level in the west, while in the eastern core 5.5 is the lighter one. Stage 6 reveals the highest $\delta^{18}O$-values, particularly in substages 6.6, 6.4 and 6.2. Notably, carbonate is on a high level during this time.

The carbon isotope profiles of both cores are very similar and appear far better suited for stratigraphical work than $\delta^{18}O$.

High carbonate contents are found only during stages 8 and 6 in both cores, and possibly in stage 5 in the eastern record. In stage 5 of the western core, two

distinct carbonate peaks occur at the end of the substages 5.5 and 5.1, while substages 5.4 through 5.2 are almost free of carbonate.

The discrepancy of high carbonate content in glacial sediments and low carbonate in the warm stages may be due to carbonate dissolution and likely relates to the impact of Greenland Sea deep water formation on carbonate sedimentation in the basin.

PALEOCEANOGRAPHIC DEVELOPMENT OF THE GREENLAND, ICELAND, AND NORWEGIAN SEAS THROUGH THE LAST 15 KA: THE DIATOM AND $\delta^{18}O$ EVIDENCE

N.K. Karpuz (Dept. of Geology, Univ. of Bergen, Norway), E. Jansen, and H. Haflidason

Downcore studies of 8 sediment cores from the Greenland, Iceland and Norwegian (GIN) Seas reveal diatom abundance, assemblage succession, paleotemperature development and light isotopic peaks related to meltwater events in the area during the last deglaciation and the Holocene.

The chronology of the cores was established by using two distinct ash layers (Vedde ash-10,600 yrs BP and Saksunarvatn ash-9,100 yrs BP) and AMS ^{14}C-dated levels. Oxygen isotope records document presence of light isotopic peaks dated to 13,200 and 14,100 yrs BP or slightly before in the eastern GIN Seas and 14,600 yrs BP in the western GIN Seas implying at least two different episodes of meltwater supply with probably different sources. The diatom analyses indicate that the surface waters of the SE GIN Seas became seasonally ice free after 13,400 yrs BP. The Bølling/Allerød interstadial complex (13,200-11,200 yrs BP) was a climatically unstable period with changing arctic/subarctic conditions. The Younger Dryas period (11,200-10,200 yr. BP) was bounded by very rapid SST variations, and characterized by arctic/polar conditions in the SE GIN Seas. First appearance of diatoms in an E-W transect indicates a time transgressive opening of the GIN Seas with favorable conditions for diatom production and preservation throughout the Holocene. A general feature of the diatom assemblage successions is a dominance of the warm Atlantic assemblage in the first half of the Holocene indicating a strong influx of Atlantic waters into the GIN Sea.

This early Holocene climatic optimum occurred between 8,000-5,000 yrs BP in the SE GIN Seas. Duration of this optimum decreased both towards the west and the north. The second half of the Holocene is characterized by generally cooler assemblages and more variable surface water conditions.

A HIGH-RESOLUTION DIATOM RECORD OF THE LAST DEGLACIATION FROM THE SE NORWEGIAN SEA : DOCUMENTATION OF RAPID CLIMATIC CHANGES

N.K. Karpuz (Geological Institute, Univ. of Bergen, Norway) and E. Jansen

We studied high resolution sediment cores from the SE Norwegian Sea which display a detailed climatic record during the last deglaciation compatible with that of Greenland ice core Dye 3. The Accelerator Mass Spectrometry (AMS) ^{14}C age control of the cores also enables us to correlate this marine record in detail with other continental records. The results indicate that the surface waters of the SE Norwegian Sea became seasonally ice free after

13,400 yr BP. The Bølling/Allerød interstadial complex (13,200-11,200 yr BP) was a climatically unstable period with changing arctic-subarctic conditions. This period was punctuated by 4 progressively more severe Sea Surface Temperature (SST) minima; between 12,900-12,800 yr BP (FD I), 12,500-12,400 yr BP (FD II), 12,300-12,000 yr BP (OD I), and 11,800-11,500 yr BP (OD II). The Younger Dryas (YD) (11,200-10,200 yr BP) represents the severest and most prolonged cold episode of this series of climatic deteriorations. It was bounded by very rapid SST variations, and characterized by arctic-polar conditions. The first real warm Atlantic water incursion to the SE Norwegian Sea took place around 10,100 yr BP, followed by a brief return to arctic conditions between 9,900-9,600 yr BP (YD II). The early Holocene climatic optimum occurred between 8,000-5,000 yr BP. A conceptual model is proposed where meltwater fluxes are suggested to cause the observed instability in the SST record.

PHYSICAL PROPERTIES OF LATE QUATERNARY CENTRAL ARCTIC DEEP SEA SEDIMENTS: PALEOCEANOGRAPHIC SIGNIFICANCE

H. Kassens (GEOMAR, Kiel, Germany), D. Mosher, K. Moran, and ARCTIC '91 Shipboard Scientific Party

ARCTIC '91 was a three-ship, multidisciplinary expedition to study all aspects of the Arctic Ocean. As part of this expedition, FS POLARSTERN carried out a major marine geological and geophysical program. A total of sixty-six marine geology stations were studied in seven different geologic regions: Nansen Basin, Gakkel Ridge, Amundsen Basin, Lomonosov Ridge, Makarov Basin, Morris Jesup Rise, and Yermak Plateau. The sediment physical properties of all geological core samples were measured at high resolution in order to enhance the paleoceanographic interpretation of each site, to link sediment cores directly to high resolution seismic reflection data, and to provide data for biostratigraphic control. Sediment physical properties included acoustic compressional velocity, shear strength, index properties, and sediment color reflectance. Preliminary results of the highest priority paleoceanographic sites are reported here.

Nansen and Amundsen Basins are dominated by young turbidite sediments. The frequency and amplitude variations of the physical property curves represent alternating sediment layers of sand and silt with layers of silt clay to clay. The Makarov Basin and Lomonosov Ridge sediments show normally consolidated behavior, with some intervals showing deviations from this trend. The deviations can be directly correlated with lithologic changes, such as event deposits of ice-rafted debris and mud clasts and, therefore, do not represent past erosional or sea-bed loading events. Physical properties from the Morris Jesup Rise sediments show high variability and no pronounced tendency with depth. The abundance of large ice-rafted component in the sediments of this region controls the sediment physical properties.

In general, the shear strength, porosity and acoustic velocity profiles show very little trend with depth below seafloor. This suggests high sediment accumulation rates in the central Arctic Ocean. First estimates of sediment accumulation rates from the Lomonosov Ridge are confirming these results. During the Holocene and oxygen isotope stage 5, the average sediment accumulation rates were 1,5 (g/ccm)/ky, whereas the average sediment accumulation during oxygen isotope stages 3 to 4 and 6 were 3 (g/ccm)/ky. These results correspond to recent sediment accumulation rates in the ice-free Norwegian-Greenland Sea.

OCEAN-ATMOSPHERE CO_2 EXCHANGE IN THE LAST GLACIAL TO INTERGLACIAL: THE CORAL HYPOTHESIS

K. Kato (Water Research Institute, Nagoya Univ., Japan)

In this study I propose that, in the last glacial to interglacial, sea level change (namely, change in continental ice volume) and subsequent weathering and growing of coral played an important role in the linkage of astronomically driven changes in the intensity of sunshine to change in the atmospheric CO_2 content.

The effect of astronomical changes on the intensity of sunshine greatly differs at high latitudes between the Northern and Southern hemispheres. However, during the last glacial-to-interglacial, climate changed at the same time in both hemispheres. Furthermore, sea-level change, determined from isotopic studies of marine foraminifera, followed change of the intensity of sunshine at high northern latitudes, and also showed the same cycles as the astronomical pacemakers did. Therefore, we must relate Northern Hemisphere seasonality changes into global climate change.

On the other hand, it has become obvious that, in the last glacial, almost all of increased ice volume was in the Northern Hemisphere and change in the atmospheric CO_2 content caused mostly global climatic change. Therefore, I thought of a linkage of the seasonality changes at high northern latitudes, ice volume change at high northern latitudes, global sea level changes, global change in the atmospheric CO_2 content, and global climatic change. A key point here is that weathering and growing of coral follows lowering and rising sea level, respectively, must link between sea-level change and change in the atmospheric CO_2 content. This is because dissolution of coral into sea water causes increased pH and alkalinity of sea water and also increased solution of atmospheric CO_2 into it, while growing of coral causes decreased pH and alkalinity of sea water and release of CO_2 to the atmosphere.

THE DEVELOPMENT OF ANTARCTIC DIATOM FLORA IN THE CENOZOIC

G. Kazarina (P.P.Shirshov Institute of Oceanology, Academy of Sciences, Moscow, Russia) and V. Mukhina

Development of the diatom flora in the Southern Ocean in the Cretaceous - Paleogene occurred locally and was caused by functioning of local upwellings. At this development stage its taxonomic composition was the same as the tropical ones. This shows the small biogeographical isolation of this region in the Cretaceous - Paleogene. In the Neogene - Quaternary the diatom flora was developed everywhere; it was distinguished by a gradually increasing degree of endemism which formed definitively at the end of the Miocene - the beginning of the Pliocene. Forming in the Neogene of Antarctic Convergence and Divergence led not only to biogeographical isolation of this region, but also to differentiation of Antarctic flora into subantarctic and high-Antarctic ones. Fossil diatom flora reflects repeated changes in location of hydrological fronts caused by climatic fluctuations during the Neogene. The most outstanding event was the Polar Front advance northwards by 6-7 degrees at the end of Miocene - the beginning of the Pliocene.

COLD SURFACE OCEAN VENTILATION AND ITS EFFECT ON ATMOSPHERIC CO_2

R. Keir (GEOMAR, Kiel, Germany)

Greater dust and aerosol concentrations in polar ice cores during glacial periods indicate a much windier climate than during interglacials. This implies that there is a much greater gas exchange rate between ocean and atmosphere during ice ages. In the modern northern Atlantic Ocean, solubility pumping of atmospheric CO_2 into newly formed deep water is maintained by northward flow of well-ventilated, warm surface waters, cooling and subsequent sinking. The potential for greater ventilation of this type of cooled surface water to lower atmospheric CO_2 is examined with a two-box model of the surface ocean. This potential is found to depend on whether the modern ocean's cold surface water would be re-equilibrated with atmospheric CO_2 on a time scale comparable to the warm-to-cold water conversion rate. If so, it is conceivable that greater ice-age polar ventilation has produced as much as 70% of the decrease observed in ice cores. There is a good inverse correlation between the concentrations of marine aerosol derived sodium (Na_m) and trapped-air CO_2 found in the Vostok ice core. The relationship is given by

$$PCO_2 = \frac{281.9\ \text{ppm}}{(1 + .00409\ Na_m)}$$

where Na_m is in ng g^{-1}. This sort of correlation would be expected if a link between polar surface water ventilation and atmospheric CO_2 concentration exists.

PELAGIC LAMINATED DIATOM OOZE IN THE EASTERN EQUATORIAL PACIFIC: A RECORD OF PEAK NEOGENE PALEOPRODUCTIVITY

A.E.S. Kemp (Dept. of Oceanography, Univ. of Southampton, UK) and J.G. Baldauf

Laminated diatom ooze has been recovered from several geographically widespread sites in the eastern equatorial Pacific during ODP Leg 138 and DSDP Leg 85 drilling. This remarkable sediment records episodes of massive primary production during the Neogene between 15 and 4.4 Ma. Mats of the (up to 4 mm long) diatom *Thalassiothrix longissima* were deposited as successive laminations at unparalleled high deep sea sedimentation rates of over 10cm/1000 years. Laminations were preserved by the physical subjugation of benthos by a diatom meshwork, rather than by low concentrations of dissolved oxygen.

Some of the main intervals of laminated sediment deposition coincide with periods of major change in the Ocean system. The occurrence of these "rare major events" of massive production and flux have major implications for the behavior of the equatorial ocean system and present unique opportunities to 1) quantify fluxes by direct measurement of individual depositional events rather then depending on interpolation from a homogenized (bioturbated) record, and 2) to study sub-Milankovitch band variability which can be related to the time scales of current studies of atmosphere/ocean interaction.

ORCA BASIN: A HUNDRED-YEAR RESOLUTION RECORD OF HOLOCENE PALEOCLIMATIC CHANGES IN THE GULF OF MEXICO

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The paleoclimatic record has been examined at high stratigraphic resolution (every 100 yrs) for the Holocene (last 9.5 kyr) in piston cores from Orca Basin, an anoxic basin in the northern Gulf of Mexico. The cores are unbioturbated, organic-rich, laminated in parts, and exhibit sediment rates of ~1cm per 10 years. Also, planktonic foraminifera and pteropods are abundant and well preserved.

Planktonic foraminiferal and pteropod assemblages are typically interglacial, but exhibit high variability throughout. Also, Early, Middle, and Late Holocene assemblages exhibit differences in average composition reflecting climatic change, with slightly cooler assemblages marking the last 4,000 years.

Quantitative changes in individual species and assemblages as a whole reveal distinct Holocene pulsation in response to paleoceanographic/paleoclimatic oscillations. Limited carbon 14 radiometry suggests that the period of this cyclicity to be ~2,300 years. A period of ~2,400 yrs has been reported for tree-ring ^{14}C concentrations; ~2,500 yrs for little ice age pulses; and 2,600 yrs in fluctuations of ^{14}C in the atmosphere, associated with fluctuation in solar activity, and it is likely that the episodes in the Gulf will be found to be synchronous with these events.

The three older faunal cycles range from 2,300 yrs to 9,500 yrs, and all resemble saw-tooth patterns. Each pulse reflects dynamic climate changes lasting between 300 and 500 years beginning with a relative warming peak, inferred to reflect strengthening of the Gulf stream loop current in the Gulf, and is immediately followed by a cool episode. The juxtaposition of the extreme climatic states of the Gulf Holocene reflect episodes of climatic disequilibrium.

The pattern of climatic change is different for the last 2,500 years compared with earlier in the Holocene. This interval exhibits both higher variability, and more frequent climatic pulses. Each cycle begins with a dramatic shift in less than 100 yrs. This interval is perhaps because of anthropogenic influences.

EARLY PLEISTOCENE GLACIAL-INTERGALCIAL DIATOM AND RADIOLARIAN ASSEMBLAGES FROM THE EASTERN EQUATORIAL PACIFIC

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Polycystine radiolaria and diatoms from ODP Hole 677A in the eastern equatorial Pacific were examined at isotopically identified early pleistocene glacial maxima and minima. Two distinct assemblages are recognized, characterizing glacial and interglacial optimums. The glacial assemblage is characterized by high abundances of the radiolarians *Theocalyptra davisiana, Botryostrobus auritus, Anthocrytidium zanguebaricum, Hexacontium enthacanthum* and the diatom species *Thalassionema nitzschoides*. The interglacial assemblage is characterized by the radiolarians *Tetrapyle octacantha, Octapyle stenozoa, Theocorythium vetulum* and the diatom *Coscinodiscus nodulifer*. A comparison of these fossil radiolarian assemblages with modern radiolarian distribution suggests that the glacial assemblage represents intensified upwelling of cold advected water via the Eastern Pacific

Boundary Current, while the interglacial assemblage indicates climatic amelioration in the eastern equatorial Pacific, with the prevalence of warm (>21°C) tropical/subtropical surface waters.

OBSERVATIONS ON CALCAREOUS DINOFLAGELLATES IN THE PHYTOPLANKTON AND SEDIMENTS OFF CAPE BLANC (EAST ATLANTIC OCEAN)

B. Kerntopf (Universität Bremen, Germany) and H. Willems

Dinoflagellates are numerous and widely distributed in Quaternary marine sediments in the form of organic walled resting spores (cysts) known as `hystrichospheres'. They are used as indicators of paleoceanographic parameters.

Several living marine peridinioid dinoflagellates also produce calcareous cysts and the coccoid, vegetative life phase of the Thoracosphaerids produces a calcareous cell wall. Calcareous dinoflagellates have recently been found in various types of sediments from (nearly) all latitudes. The lateral distribution of individual species and the relation to oceanographic parameters is poorly known. The role played by vegetative and cystic stages of some species in red tides has not yet been established.

Samples were obtained during the M 20/1 cruise of RV METEOR from the first 25 m of the water column and the first 33 cm of the sediment. Site position was approximately 21°10'N, 20°42'W west off Cape Blanc at 4000 m water depth.

The relative frequencies of calcareous dinoflagellates in the euphotic zone and in the sediments below were calculated and the individual taxa identified. Few species of Thoracosphaerids are evenly distributed in the first 25 m of the surface water. The quantity and variety of cysts rises slightly with depth. This pattern of calcareous dinoflagellate assemblages is also found in the sediment. Species associations and diversity have been related to surface water environment with its biologic-ecologic phenomena and hydrodynamic system.

PLEISTOCENE ICEBERG TRANSPORTATION IN THE NORTH ATLANTIC ACCORDING TO DATA ON ERRATIC STONE MATERIAL

G.S. Kharin (P.P. Shirshov Institute of Oceanology, Academy of Sciences, Russia)

Dredging, trawling and grab samples carried out over various morphostructures in the different regions of the Atlantic Ocean provided a great amount of rudaceous stone material, the composition of which differs sharply from that of the oceanic crust rocks. The collection of such material is especially abundant in the North Atlantic and Norwegian-Greenland basin where it was many times defined as ice-iceberg transportation (Ruddiman and McIntire, 1976; Soldatov and Kharin, 1979; Lisitsin and Kharin, 1991). The criteria for distinguishing local rock stone material from rudaceous one of ice-iceberg transportation was established. Detailed study of the latter, absolute age determination for erratic material, and comparison with continental rocks enabled to reveal the regularities of rudaceous material distribution over the North Atlantic bottom and to outline its petrographic provinces. These provinces are related to iceberg delivery from definite continental centers of glaciation.

Iceberg transportation of rudaceous material from the centers of glaciation was observed up to 20° N in the North Atlantic during Late Pliocene and Pleistocene. Judging by quantitative distribution of rudaceous material in the bottom sediments of the North Atlantic there were two main directions of iceberg movement during Pleistocene: 1 - in the western part of the ocean it was from Greenland and Labrador Peninsula to the south along North American shores; 2 - in the eastern part of the ocean it was from the British Isles, Iceland, Faroe-Rockall region to the south and south-east. In modern times the transportation of iceberg material in the first direction is still continued while the second one has lost its significance.

CORRELATION BETWEEN LABORATORY AND *IN SITU* PHYSICAL PROPERTIES

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A continuous suite of shipboard laboratory velocity and physical properties of Site 846 was correlated to *in situ* log data. The site was selected because of its relatively thick (422 mbsf) sediment sequence to middle Miocene. Another advantage of the site is to study the effect of alternating biogenic silica (mostly diatoms) on physical properties. The observed two prominent fluctuations in index properties occurred around 60 mbsf and 300 mbsf reflect the influence of compositional changes. Compared to velocity, differences between laboratory and *in situ* log measurements for bulk density and porosity are very small throughout the entire range of depths studied. The *in situ* velocity correction curve does not match well for the diatom-rich intervals. Laboratory sonic velocity for Site 846 cannot be corrected simply by porosity rebound. Both sediment composition and depth should be considered to correct the laboratory velocity to *in situ* values.

PRIMARY PRODUCTION: THE DIATOM RECORD IN EAST ATLANTIC SURFACE SEDIMENTS

J.J. Knaack, M. Sarnthein (Geologisch-Paläontologisches Institut, Kiel, Germany) and U.Treppke

Marine plankton production and the vertical flux of organic matter strongly contribute to the carbon transfer from the surface to the deep ocean and to the deep-sea sediment. In this study we present a new transfer function to deduce paleoproductivity estimates from both the absolute diatom abundance and diatom species counts. The diatom data are based on counts of Kiel and Bremen samples and additionally on counts by E.Pokras and B.Molfino (1986). The data base covers the tropical and northern East Atlantic (10°S - 30°N, 30°W - 10°E).

In the high-production belt of the equatorial divergence zone diatom abundance reaches more than $20x10^6$ frustules per gram sediment, whereas the abundance is generally low in near-shore high production zones, except off Nigeria and Gabon, and outside, in the "blue ocean" (0 - $1x10^6$ frustules/g). Three levels of oceanic productivity are recorded in the diatom species assemblages :

1. The high production assemblage (endmembers: *Thalas-sionema nitzschioides, Rhizosolenia spp.*) includes weakly silicified species and high amounts of resting stages (*Chaeto-ceros*) and is linked to coastal upwelling that occurs off the coast of Côte d'Ivoire during northern summer.

2. The moderate-to-low production assemblage (with *Rhizo-solenia bergonii*) marks the equatorial divergence zone, characterized by an extremely high diatom abundance.

3.The low production assemblage is enriched in dissolution-resistent species (*Paralia sulcata, Azpeitia nodulifer*) and occurs in the "blue ocean" area.

A DETAILED INVESTIGATION OF THE BENTHIC REGIME IN THE CLARION-CLIPPERTON GEOLOGICAL PROVINCE OF THE PACIFIC

E.A. Kontar (P.P. Shirshov Institute of Oceanology, Moscow, Russia)

The study area is known to abound in manganese nodules related to the gently sloping sides of the abyssal hills. Benthic current features of the Clarion-Clipperton geological province, oceanological and sedimentalogical situations, as well as physical properties of the sediments and nodules are taken into account to estimate the possible bottom sediment disturbance during the paleobenthic storms. Simultaneous measurements of surface, deep and benthic currents are discussed. Three pop-up bottom stations were placed over the Clarion-Clipperton Fracture Zone. They were equipped with sediment traps and instruments for measuring current speed, temperature, salinity, pressure and the content of oxygen dissolved in the water. On the North Passat Current an anticyclonic eddy was found. Its center was about 250 km. Anomal distribution of oceanographic parameters in the deep layer and measured current features may be explained by penetration of the eddy to the bottom that resulted in observed benthic current intensification (the benthic storm). Measurements showed variation in O_2 content and in the dynamic characteristics. The benthic storm lasting longer than 50 h, was recording within a 36-day spell. The facies condition of manganese nodule formation was found to be associated with paleobenthic dynamics.

BENTHIC FORAMINIFERA IN MODERN GLACIAL FLOOR SEDIMENTS OF THE BARENTS SEA

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Four grab samples and five gravity cores from Spitsbergen and Novaya Zemlya inlet, affected by calving glaciers, have been studied. The living assemblage is clearly distinguished from the open Barents Sea. *Cassidulina reniforme* here substitutes common dominant species of muddy sediments of the Barents Sea shelf, *Melonis barleeanus, Reophax scorpiurus, and Proteonina atlantica*. Arenaceous forms are almost absent. The standing crop (100 spec./10 cm^2) is similar to the open sea, but biomass (0.02 g/m^2) is one or two orders of magnitude lower. Living foraminifera comprise more than 50% of the total assemblage. The taphonomic pattern is typical of the northern Barents Sea. Postmortem dissolution diminishes the number of calcareous tests. Seasonal and perennial variations of species compositions should be averaged. *Allogromiina* and *Textulariina* disappear down-core. The result of the taphonomic process is a fossil assemblage composed mainly of calcareous forms. The modern taphocoenoses from the glacial floor sediments in the inlets and from the open shelf deposits in the ice-covered northern Barents Sea are similar. They are dominated by *C. reniforme* and *Elphidium clavatum* and have low abundance and diversity. Peculiar characteristics of the glacial-marine assemblage, which are believed to be caused by the highly stressed ecological environment, are the high percentage of occurrence for juveniles, and the paucity of large species and larger specimens. The most prominent faunal peculiarity of the inlets is the rather high percentage of *Quinqueloculina stalkeri*.

LATE APTIAN-MAASTRICHIAN PLANKTONIC FORAMINFERIDA WATER-DEPTH STRATIFICATION: EVIDENCE FROM THE SERGIPE BASIN STRATA, NE BRAZIL

E.A.M. Koutsoukos (Petrobras - Cenpes / Divex, Cidade Universitária, Rio de Janeiro, Brazil)

New evidence is presented on the relationship among oceanographic conditions, pelagic niches and life-cycles of Cretacous planktonic dwelling Foraminiferida. High resolution microbiostatigraphic, paleoenvironmental studies carried out in the upper Aptian-Maastrichtian strata of the Sergipe Basin (sections onshore and offshore), integrated with detailed sedimentological and geochemical studies, allows us to infer a refined relative water-depth stratification model for the planktonic Foraminiferida morphotypes. Furthermore, models are proposed for the ecophenotypic, species diversity and evolutionary responses of *Globigerinina* to changing oceanographic conditions, of regional and/or worldwide scale

It is shown that sedimentary sequences from marginal neritic environments (i.e., shallower than 100 m of water depth) have the greatest potential to provide stepwise control on the relative paleobathymetric distributions of the planktonic assemblages. This is a particularly significant approach to paleoceanographic and biogeographic studies of Mid-Cretaceous carbonate shelf sequences.

CHANGING PALEOCEANOGRAPHIC CONDITIONS, THE TROPHIC RESOURCE CONTINUUM, AND THE RESPONSE OF THE FORAMINIFERAL COMMUNITIES: A CASE STUDY FROM THE CRETACEOUS OF THE SERGIPE BASIN, BRAZIL

E.A.M. Koutsoukos (Petrobrás - Cenpes, Rio de Janeiro, Brazil)

Foraminiferida diversity patterns are a direct response to paleoceanographic conditions and can reflect long-term cumulative changes produced by seasonal cycles in sea-level, sediment type, redox conditions and rates of food supply. Diversity patterns are, therefore, particularly sensitive recorders of variations in the "trophic resource continuum" (T.R.C.), i.e., to the entire conceivable range of available resource levels at a specific time and depositional setting.

The number of benthonic Foraminiferida species recovered from the upper Aptian-Maastrichtian succession of the Sergipe Basin, in northeastern Brazil, progressively decline from the middle Albian to the early Coniacian, with peak diversities in the Late Aptian-Early Albian, through a series of small radiation/diversification "blooms" by k-selection. These are then determined by a reduction of species vía extinction events and/or environmental turnovers (T.R.C. contraction, decreasing spectrum of nutrient heterogeneity, increasing mesotrophic/eutrophic conditions, selected trophic groups and r-selected biota).

A sharp increase in diversity occurred during late Coniacian-Maastrichtian times, with a maximum in the early Campanian (paleo-bathymetric maximum of the basin). Long-term, high stands of sea level during the Late Cretaceous, coupled with widespread oxic pelagic conditions (expanded T.R.C., high spectrum of nutrient heterogeneity, widespread oligotrophic conditions in outer neritic oceanic settings, and complex trophic structures), contributed to create niches and promote evolutionary diversification through k-selection, with the development of polytaxic Foraminiferida biota.

TERTIARY SEA LEVEL CHANGES ON THE ICELAND-FAEROE RIDGE

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The Iceland-Faeroe Ridge was formed in Paleocene and Eocene during the opening of the Northeast-Atlantic. It prevented the free exchange of water masses between the Iceland Basin and the Norwegian-Greenland Sea in the Early Tertiary.

The subsequent thermal subsidence of the Iceland-Faeroe Ridge is documented in the sedimentary structures investigated by high-resolution reflection seismic measurements. The correlation with geological epochs is given by DSDP site 336, leg 38, where all sequences except Miocene have been observed. This prominent hiatus is mapped at the upper part of the ridge while a sedimentary sequence of probably Miocene age has been found further downslope to the Norwegian-Greenland Sea.

The Eocene sediments are characterized by a high degree of transparency. Nevertheless, some internal reflectors can be recognized. A series of parallel reflectors is visible above the basaltic basement, partly overlain by foreset beds. This might indicate the onset of sea-level changes at the northern flank of the Iceland-Faeroe Ridge already during Eocene.

RECONSTRUCTION OF DEPOSITIONAL ENVIRONMENTS FOR CARBONATE BUILDUPS OF DALMIAPURAM FORMATION (EARLY CRETACEOUS) IN TIRUCHIRAPALLI DISTRICT, TAMIL NADU, INDIA

R. Krishnamoorthy (Ocean Data Centre, Institute for Ocean Management, Anna Univ., Madras, India)

The present study area bordering the Ariyalur area, towards the west in the Tiruchirapalli District , Tamil Nadu state, is limited within the latitudes 10° 56' 21" to 11° 21' 10" and longitudes 78° 45 to 79° 7' 30". This area where these organogenic rocks are exposed is more or less a plain land and interrupted by shallow limestone quarries. The purpose of this work is to define the paleoenvironmental conditions under which these rocks were deposited. The study involves an elaborate field work, identification of major/minor lithotypes, a detailed petrographic account of carbonate rocks, and distribution of MgO/CaO, important trace elements, and clay mineral species. Staining methods are adopted to study the mineralogical variations of Scanning Electron Microscopy (SEM) for secondary mineral segregation etc. The entire study has been synthesized for a meaningful reconstruction of depositional environments during the early part of the Cretaceous.

Petrographic studies of these limestone bodies show that they are largely made up of mudstone, wackestone, and packstone. These petrographic types and the occurrence of certain clay mineral ingredients, such as kaolinite, montmorillonite and illite, along with the distribution of a few important trace elements (Pb, Ni, Sr, Mn and Fe) suggest that the deposition of the re-efoidal limestones took place in the shallow warm water conditions above the wave base of the paleo-sea of comparatively less salinity under the tropical climatic regime.

THE LAST GLACIAL-INTERGLACIAL TRANSITION IN THE SOUTH CHINA SEA RECORDED BY STABLE ISOTOPE OF BENTHIC AND PLANKTONIC FORAMINIFERA

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Piston cores from continental slopes off southern China and off northwestern Borneo were analyzed for foraminiferal carbon and oxygen isotopes. The glacial-interglacial transition in the marginal basin of the South China Sea is interrupted by the Younger Dryas cold episode recorded by planktonic oxygen isotopes in cores with a high sedimentation rate. The preceding period coinciding with the first meltwater pulse is documented in cores up to a water depth of about 1000 m by a time-lagged small fluctuation in the benthic oxygen isotope records. In cores from greater water depths benthic oxygen isotope values are constant at glacial high levels until the beginning of the Younger Dryas and rapidly decrease at the end of this episode. The deep-water benthic carbon isotope signal shifted by + 0.5 ‰ from low glacial to interglacial levels. This shift started at shallow sites earlier (during the Younger Dryas) than in deep sites (after the Younger Dryas). Generally, the main change from glacial to interglacial conditions occurred in the deep South China Sea after the Younger Dryas, this is by more than 2000 years later than in the Atlantic Ocean.

AN EARLY CAMPANIAN PALEOCEANOGRAPHIC EVENT IN THE NORTH ATLANTIC AND WESTERN TETHYS?

W. Kuhnt (Geological Institute, Univ. of Tübingen, Germany)

Complete Upper Cretaceous pelagic sections in the North Atlantic and Western Tethys have been examined for sedimentary and biotic changes during the Santonian and Campanian (roughly corresponding to the Cretaceous Oceanic Anoxic Event 3 of Jenkyns 1980). Studied sections include DSDP Holes 368, 385, 386, 398D, 603B, ODP Hole 641A and outcrop sections in northern Morrocco, southern Spain, at Zumaya (northern Spain), Gubbio (Italy), Bad Reichenhall (Bavarian Alps) and the Romanian Eastern Carpathians. The distribution of benthic foraminifera and planktic microfossils, as well as geochemical and stable isotope data, are indicative of changes in the composition of surface and deep water masses during a short time interval in the early Campanian (*Globotruncanita elevata* planktic foraminiferal zone, *Goesella rugosa/Hormosina gigantea* benthic foraminiferal zone, reversed part of Chron 34 of the paleomagnetic timescale). Characteristic features during this interval include: (1) increased importance of pelagic carbonate ooze and biosiliceous, radiolarian-rich sedimentation; (2) geochemical and micropaleontological evidence for deep-water oygen deficiency; (3) low-diversity assemblages of opportunistic deep water benthic foraminifera, followed by an important radiation, and (4) extinction of several major groups of planktic foraminifera.

The available isotopic data point to a short-term warming, and flooded shelf areas during the corresponding transgressive cycle may have been a source for increased formation of warm salinar bottom waters. I speculate that this short-term change in bottom water or mid-water masses, along with locally increased upwelling and surface productivity, may have caused the observed paleoceanographic and biotic changes.

A COMPARISON OF THE GLACIAL CIRCULATION RECORD OF THE EASTERN NORTH ATLANTIC AT OXYGEN ISOTOPE STAGE 2 AND 6

A. Kuijpers (Geological Survey, Copenhagen, Denmark), L. Bornmalm, and K. Winn

A detailed stable isotope and calcium carbonate stratigraphy was compiled for Core 226 (water depth 3100 m) collected by the Swedish Albatross Expedition from the Cape Verde Plateau. Additional stratigraphic information has been acquired from cores of the lower slope region (4000-4200 m) of the Atlantis-Meteor seamount complex taken during later German and Dutch expeditions.

In core 226 the benthic foraminifer species *Cibicidoides wuellerstorfi* exhibits a $\delta^{13}C$ minimum of -0.35 per mil in the oxygen isotope stage 6, while stage 2 values are not below zero. The benthic $\delta^{13}C$ minimum is not coincident with the planktonic minimum and, therefore, may be interpreted as a bottom-water signal and not as an indication of surface water productivity. We conclude that in stage 6 southern source water masses with their typically low $\delta^{13}C$ signature were much more dominant in the deep water mixture of the eastern North Atlantic than in stage 2.

Asymmetric sedimentation around the Atlantis-Meteor sea-mount complex with erosion along the SW flank points to enhanced northerly deep water flow immediately prior to the stage 6 glacial maximum.

Only for *Neogloboquadrina dutertrei* the $\delta^{13}C$ record of Core 226 shows extremely low values of near zero in early stage 6 and in 7. This species dwells at greater water depth (50-255 m) than the other planktonic species. The negative $\delta^{13}C$ excursion could originate from enhanced advection of South Atlantic Central Water, which apparently did not occurr in stage 2. Moreover, continuous presence of *Globorotalia menardii* in Core 226 during $\delta^{18}O$ stage 6 suggests higher sea surface temperature and less intense upwelling in that region than in stage 2, when this species was absent.

CONTINENTAL LOESS DEPOSITS: A RECORD OF CLIMATIC VARIABILITY DURING THE NEOGENE

G. Kukla (Lamont-Doherty Geological Observatory, Palisades, NY, USA)

Paleoclimatic records from the deep-sea floor from the Chinese Loess Plateau and from the loess deposits in Europe and central Asia show in the last 3 million years more than 100 oscillations of mild and cool global climates with an amplitude larger than any recorded during the last 10,000 years. Periodicity of these gross past climate changes agrees with that of the earth´s orbital perturbations. While the amplitude of paleoclimatic cycles recorded in the deep-sea sediments is relatively uniform, several of the cold climate shifts inferred from the loess record were exceptionally severe. They include Chinese loess units L1, L2, L4, L6 and L9, L13, L15, WL1, WL2, WL3, and WL4. The uppermost five correspond to oxygen isotopes stages OXY 2, 6, 12, 16, and 22. The last major climate deterioration of such type occurred about 0.5 million years ago. Although problems remain with the correlation of classical glacial stages with the deep-sea and loess records, it is now well established that the upper zone of L1 and the OXY 2 correspond to the Weichselian and Late Wisconsin continental ice advances. Upper L2 and late part of OXY 6 correspond to the Warthe and Late Ilinoinian ice advances, L5 with OCY 12 to the Elster advance, and OXY 16 and 22 to the Kansan and Nebraskan glaciations.

Correlation of Drenthe and main Illinoian advance with the loess sequences and with the deep-sea chronology remains unclear. Classical alpine glacial stages can be also correlated with European loess deposits. The gravels of the lower terrace representing the Wurm were deposited in the last two glacial cycles and those of the Riss terrace appear to correlate with L5 to L2 or with OXY 12 to 6. The exceptional intensity and deep southward ice penetration during only some of the cold intervals has no explanation in Milankovitch forcing. The fact that the ocean and that major ice advances closely correlate with terraces even in areas far away from former glaciers points to a probable link of the extreme glaciations with the episodic crustal uplift. Intermittent uplift of the mountains and subsidence ot the adjacent basins could have been accompanied with changes of the depth and shape of the sea-floor sills and passages influencing the oceanic circulation.

PALEOPRODUCTIVITY OF THE SOUTHERN OCEAN INFERRED FROM RADIONUCLIDE TRACERS

N. Kumar (Lamont-Doherty Geological Observatory, Palisades, NY, USA), R. Gwiazda, R.F. Anderson, P.N. Froelich, B. Dittrich, P. Kubik, and M. Suter

The objectives of the study were: (1) to determine if "boundary scavening" of ^{231}Pa and ^{10}Be takes place inthe southern Ocean, (2) to check if there were large changes in Southern Ocean productivity during glacial -interglacial cycles, and (3) to help resolve the differing interpretations of Southern Ocean productivity changes based on different tracers, e.g., Cd/Ca and $\delta^{13}C$.

For this purpose, core RC 13-259 from latitude 54° 53' S, longitude 4° 56' W and 2677m water depth was chosen. The sediment record which goes back to 450 ky has previously been dated by $\delta^{18}O$ and by correlation with other ^{14}C-dated cores. There are large variations in total accumulation rate, with percent opal varying from ca. 30% in glacials to ca. 80% in interglacials.

Our results show that: (1) Flux of ^{231}Pa to the sediments exceeds its production in the water column during all climate stages, confirming that the Southern Ocean is a net sink for ^{231}Pa. (2) Flux of ^{10}Be to the sediments during all climate stages is greater than its global average production rate confirming that the Southern Ocean is a net sink for ^{10}Be. (3) Highest fluxes of ^{10}Be are seen in neither peak glacials nor in peak interglacials but rather in intermediate stages. (4) Initial unsupported $^{231}Pa/^{230}Th$ ratios can be measured back to ^{18}O stage 6, and vary systematically over a range from ca. 0.13 to ca. 0.28, with high values in interglacials and low values in glacials indicating that biological productivity at this site is indeed greater during interglacials than during glacials.

ATMOSPHERIC CO_2 AND MESOZOIC PALEOGEOLOGY

L.R. Kump (Earth System Science Center; Dept. of Geosciences, PA State Univ., University Park, USA)

The spatial distribution of the different type of rocks exposed to weathering processes (i.e., the paleogeology) is likely to have been an important factor in the regulation of oceanic chemical and isotopic composition through the Mesozoic. In addition, temporal trends in paleogeology may have effected global climate changes, via the important role the lithology plays in determining whether chemical weathering serves as a long-term sink for atmospheric CO_2 (only silicate rocks provide a net sink).

Despite its importance, there is surprisingly little information available on the geology of past times. We have developed a simple technique for developing paleogeologic maps, using the primary lithological data of A.B. Ronov and colleagues (e.g., Bluth and Kump, 1991; *Amer J. Sci.*, 291: 284-308). Ronov's most recent compilation of Mesozoic and Cenozoic data has just become available, and we have incorporated these data into a new set of paleogeologic maps for the Mesozoic.

These maps are then used, in conjunction with the global-climate-model results of E.J. Barron and colleagues, to calculate rates of chemical weathering and CO_2 at discrete times in the Mesozoic. These calculations also provide a means for determining the carbon, sulfur, and strontium isotopic composition of the global riverine input, useful to other modeling studies. We find synergistic interactions between the spatial distributions of climate and lithology that enhance chemical weathering rates, but not necessarily those of silicate rocks, during intervals of the Mesozoic for which other techniques indicate elevated levels of atmospheric CO_2 and warm climates. These interactions reinforce the suggestion that paleogeologic changes have been important factors in the long-term cycles of the elements.

NORTH ATLANTIC SURFACE WATERS AND THE CONVEYOR BELT: VARIABILITY DURING THE PAST 30 KA

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Surface water salinity at high latitude is supposedly one of the major constraints on deep-water convection and NADW formation during the last glacial period. The deglaciation is a particularly difficult time to test this idea using forminiferal isotopic ratios, as both surface water salinity and temperature change rapidly, and few cores contain regular accumulation of the reliable benthic foraminifera species *Cibicides wuellerstorfi*, which is used for the deep water $\delta^{13}C$ reconstructions. Six major meltwater events occurred about each 10 kyr during the last glacial (the so-called "Heinrich layers"). We have recorded them by $\delta^{18}O$ analysis of the planktic foraminifera *N. pachyderma s.* at high resolution in 3 high sedimentation rate cores from the North Atlantic Ocean (SU 90-08 43°N 30°W 2000 m depth, NA 87-22 55°N 14°W 3000 m and ODP 609 50°N 24°W 3900 m) Large $\delta^{18}O$ anomalies (= -1%) mark each events. Except for HL2 (=19 ka BP), the benthic oxygen record (analysed in 2 of the cores) shows corresponding $\delta^{18}O$ anomalies (of about -0.5%) with approximately 1 ka lags, tracking the penetration of "spiked" surface water. Lowering of the Cibicides $\delta^{13}C$ appear more significant for meltwater events HL1 (=13.5 ka) than for the earlier ones, within isotopic stage 3. Implication of these results for deep-water convection in the North Atlantic will be studied using simple box models.

THE SOUTHERN OCEAN ROLE IN GLACIATION CYCLES: INFERENCES FROM A STUDY OF CORE MD 88-770

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According to a recent scenario, glaciation cycles begin with a decrease in the flux of Northern Source water originating in the Norwegian-Greenland Sea, which reduces heat flux to the Southern Ocean, in turn increasing sea-ice coverage and driving wind-stress fields equatorward (Imbrie at al., submitted). At the same time Southern Ocean deep waters are geochemically isolated from other deep-water masses and from surface water ventilation, enriching the deep waters in dissolved carbon and reducing atmospheric pCO_2. This idea derives in part from a composite record of planktic $\delta^{13}C$ from the subantarctic Indian Ocean which shows that over the past 500 kyr, planktic-benthic $\delta^{13}C$ increase about 1‰ during glacial intervals. These changes in surface-deep carbon partitioning imply CO_2 draw-down by the Southern Ocean during glacial intervals which lead foraminiferal $\delta^{18}O$ (Howard, PhD Thesis, 1992). This idea has not been tested within the Southern Ocean itself, for lack of continuous high resolution records constrained by benthic foraminifera $\delta^{18}O$. We present the analyses of core MD 88-770 (46°S 96°E 3200 m depth), which covers the last 250 ka. We show that: 1) rapid changes in planktic *N. pachyderma s.* $\delta^{18}O$, SST

and benthic *C. wuellerstorfi* $\delta^{13}C$ are synchroneous at major transitions; 2) the benthic $\delta^{18}O$ lags these proxies by = 5 kyr; and 3) the long-term shifts of benthic $\delta^{13}C$ and $\delta^{18}O$ are similar. These results are in general agreement with Imbrie et al.

Ref: J. Imbrie et al.: On the structure and origin of major glaciation cycles: 1 linear responses to Milankovitch forcing (submitted).

PALEOCEANOGRAPHY OF THE SUBANTARCTIC INDIAN OCEAN

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High resolution records of the biogenic fluxes ($CaCO_3$, Opal $BSiO_2$ and total organic carbon-TOC) from core MD 88770 in the subantarctic Indian Ocean are compared for the last climatic cycle. Geological records of these proxies of the past sea surface biological production are also compared with both the distribution of radiolarian *Cycladophora davisiana,* a species of intermediate depths and the benthic foraminifera assemblages characteristic of deep sea microbiota. The flux patterns of $BSiO_2$ and TOC correlate well whereas carbonate fluxes show few ralation with them, often being out of phase.

The highest fluctuations in the flux patterns of biogenic particulate material have taken place around 135, 75 and 17 kyr B.P. and could precede the more important atmospheric pCO_2 changes although the time scales for comparing ice core CO_2 and marine sedimentary records are yet under discussion. Large increase of $BSiO_2$ and TOC during stage 6 and essentially 2 are comformable to high glacial productivity related to a large shift in surface isotherms equatorward. Linear regressions of both radiolarian *C. davisiana* fluxes and of benthic foraminifera *M. barleanum* fluxes to the flux of TOC show correlations with $r^2>0.8$ However, surface ocean productivity related to more or less TOC transfer through the water column to the deep sea floor is not the only changing variable explaining the response of organisms at intermediate and deep depths.

PRODUCTIVITY AS A MAJOR CONTROL OF SHORT-TERM ORGANIC CYCLICITY IN THE KIMMERIDGE ROCKS OF YORKSHIRE (U.K.)

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Recent sedimentological and stratigraphical studies on the organic-rich Kimmeridge Clay Formation of Yorkshire have revealed a cyclic distribution of the organic carbon content with different periods of time. The shortest period (one meter thick) has been found as representing about 30,000 vears (Herbin er al., 1991). As shown by petrographical (optical and electron microscopies), mineralogical and geochemical investigations, both primary production and biogeochemical degradation changes have been recorded along the series.

Because dilution by detrital minerals and biogenic carbonates is unable to explain the TOC variations, and because of the phytoplanktonic nature of organic matter, the organic cyclicity is thought to be induced by changes in productivity-related organic supply. Sulfate reduction indices indicate that these changes are accompanied by variations in organic carbon burial efficiency while redox conditions were relatively unmodified during the deposition time. The highest burial efficiency was not found to be associated with the highest organic carbon contents, although the latter correspond to the highest input of organic carbon contents. This is due to an enhanced degradation by sulfate reduction related to the increasing proportion of the exported metabolizable organic matter as the productivity increases.

Transmission electron microscopy studies show that the preserved organic matter is mainly made of resistant components. This character is either biologically inherited (resistant ultralaminar structures from algae or bacteria) or acquired through the degradation processes during exportation and early diagenesis.

50-METER PISTON CORES TAKEN IN THE TROPICAL INDIAN OCEAN (SEYMAMA/SHIVA Expedition)

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The french research and supply vessel "Marion Dufresne", operated by the administration of the French Austral and Antarctic Territories (T.A.A.F.), has retrieved a series of long piston cores during a 28-day journey in the equatorial Indian Ocean. The goals of the expedition were two-fold: to study the effects of Quaternary cyclic climatic changes on ocean circulation, and to obtain a long stratigraphic record from the sediments deposited in the deep Central Indian Ocean basin beneath the equator.

During the cruise, the first extensive use of a T.A.A.F.-designed long piston corer allowed recovery of a unique set of 24 cores, ranging in length from 22 to 54 meters in sediments as varied as diatomaceous clays, carbonate oozes, and carbonate sands. We emphasize the following points: 1) 10 cm diameter cores over 30 meters and sometimes over 50 meters in length have been obtained routinely, and a total of about 800 m of sediment has been recovered; 2) recovery rate was very high and the state of preservation was excellent in all cores; 3) penetration was as good in calcareous as in clayey and siliceous sediments; most of the carbonates were deep-sea foramnanno oozes, and at least three 35 m cores, composed almost exclusively of foram sand, were recovered at water depths of 525, 500, and 354 meters, respectively; 4) although a rather large vessel and a powerful winch are necessary to handle the long and heavy pipe, no other special equipment is required to operate the corer in water depths of 4000 meters. Beyond that depth a kevlar cable is necessary to handle the weight of the longest configurations of the corer; 5) despite the heavy weights and long pipes that must be handled on the vessel, each coring station does not take more than 3 to 5 hours, depending on the water depth. Preparation time between cores does not exceed 3 hours.

The cores yield a unique high-resolution record for the entire Quaternary in various depths and sediment types in the equatorial Indian Ocean. Physical properties, magnetic susceptibility, isotope stratigraphy, and analysis of organic matter, together with fine-tuned biostratigraphy allows for a detailed analysis of the relation between quaternary climate, ocean circulation and monsoon influence.

SANTA BARBARA BASIN VARVE RECORD OF THE LAST 500 YEARS

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The anoxic, laminated sediments in the central Santa Barbara Basin (SBB) off California are well known for their high resolution record of past conditions of upwelling, El Niños and other climate-related processes. The varves contain alternating "light" and "dark" laminae with distinct density and compositional differences ascribed to (1) seasonally varying sources of terrigenous and biogenic particles, (2) an annual cycle of oxygen replenishment and depletion in bottom waters, and (3) bacterial (*Beggiatoa*) growth (and associated bacterial mat) at the sediment-water interface.

Diatom and foraminifera stratigraphy yields an estimate of the course of biological production across crucial intervals (e.g., El Niño (EN) years, the 1835-1840 *Macoma* event, at the end of the Little Ice Age). The effects of EN phenomena are clearly seen as decreases in total diatom flux and increases in the relative abundance of warm water species advected from the south.

Shells of the pelecypod *Macoma leptonoidea* are present in a unique thin layer dated A.D. 1840. The shell layer provides evidence for a sudden local extinction of macrobenthos by suffocation. Special conditions of decreased productivity and increased oxygen content in the sub-sill bottom allowed the expansion of benthic populations for a few years prior to 1840.

The isotopic composition ($\delta^{13}C$) of sedimentary organic carbon provides clues to the history of storms. The destruction of kelp forests in the SBB area by severe wind and wave events produces strongly ^{13}C-enriched kelp-derived particles which contribute significantly to sedimentary organic matter.

THE MID-CRETACEOUS SUPERPLUME EPISODE

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A calculation of the Earth´s ocean crustal production budget for the past 150 Ma reveals a 50% to 100% increase in world total ocean crust production between 125 and 80 Ma. The oceanic plateau-seamount chain component of this pulse shows a 300%-500% increase during this same period. This is primarily a Pacific Ocean phenomenon with an abrupt onset, and peak production rates occurred about 120 Ma. The pulse decreased in intensity through the Late Cretaceous, and ocean crustal production returned to “normal” about 30 Ma. I interpret this pulse as due to one or several very large mantle plumes that rose from the core/mantle boundary and erupted beneath the mid-Cretaceous Pacific Basin. The present-day South Pacific “superwell” under Tahiti is probably the nearly exhausted remanent of the original upwelling, and low viscosity conduits have existed down to the core/mantle boundary in that region for >125 Ma.

A wide variety of geological consequences are likely to be associated with this superplume episode including: (1) the rise in eustatic sea level culminating in the Turonian; (2) the rise in paleotemperature culminating in the Mid-Albian; (3) the Mid-Cretaceous black shale episodes whose onset at the Selli Level in the Early Aptian are synchronous with the ocean crustal production maximum; (4) a peak in world oil production between the Albian and Santonian; (5) the Mid-Cretaceous granite-forming episodes of the North and South American Cordilleria; (6) the kimberlite productivity between 120 and 80 Ma in the South and West Central Africa, Brazil, Australia, Siberia, and the USA; and finally (7) the cessation of magnetic reversals during the normal superchron between the Aptian and Santonian (124 to 83 Ma).

A DATABASE FOR GLOBAL SYNTHESES OF NEOGENE DSDP AND ODP MICROFOSSIL DATA

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A comprehensive synthesis of Neogene deep sea planktonic microfossil occurrence data has been undertaken in order to study patterns and infer environmental mechanisms of macroevolutionary change. Radiolarian, diatom, planktonic foraminifera and calcareous nannofossil range chart data from over 100 globally distributed DSDP and ODP holes with relatively good stratigraphy, recovery, and microfossil preservation have been entered into a relational database. New age-depth plots based on a revised Neogene biostratigraphic framework have been created for each hole, and used to estimate the numerical age of each sample in the database. All taxonomic names in the database have been checked for validity, and if necessary synonymized. Custom search and report software uses synonymy, hole and age information to generate global range charts and longevity information for taxa; and to compute species richness and evolutionary turnover statistics for user defined groups of samples or taxa. The database currently contains ~200,000 occurrence records, ~100,000 other data records, and runs on a Macintosh computer under 4th Dimension. Searches and reports usually require only a few minutes.

Although still in progress, some initial results of our macroevolutionary analyses will be given. The database may also be used for research in deep sea stratigraphy, and to improve microfossil taxonomy. Limitations of existing holes and data, and suggestions for future microfossil data collection will be discussed.

REGIONAL VERSUS OCEANWIDE TRANSFER FUNCTIONS: PALAEO-TEMPERATURE ESTIMATION INTHE WESTERN PACIFIC IN THE LATE QUATERNARY

J. Le (Godwin Laboratory for Quaternary Research, Univ. of Cambridge, U.K.) and N.J.. Shackleton

The foraminiferal faunal compositions of a well preserved deep-sea core, ERDC-93P, from the western equatorial Pacific(2°14.5'S, 157°00.5'E, 1619m) were examined over the last 500 kyr at intervals of approximately 5 kyr. Sea-surface temperature (SST) was estimated using both regional and oceanwide transfer functions (Imbrie and Kipp, 1971). The oceanwide transfer function (OTF) was calibrated from 499 core-top samples distributed over the whole Pacific Ocean, while the regional transfer function (RTF) was calibrated from 155 of those 499 core-top samples distributed in the western tropical Pacific Ocean. The estimated SST shows in-phase fluctuations with global ice volume, as indicated by oxygenisotope ratios. Estimates of cold season SST given by OTF were systematically about 1°C lower than those given by RTF. Estimates of warm season SST by OTF show parallel fluctuations with their corresponding

cold season SST estimates, whereas estimates of warm season SST by RTF display little variation between glacial and interglacial periods.

Examination of time-series variations of the relative abundance of individual species supports an inference that the estimates given by RTF are more reliable than those given by OTF. Experimental calibrations with hypothetical data show that a transfer function tends to show some regularity in its residual distribution due to its imperfect modelling. Mathematical examination indicates that the transfer function model in fact may allow the relative abundance of a species to have differing associations with temperature (or any other environmental parameter) in different regions with very different faunal structures. This may not have been realized in the major assumption of transfer function method that species have systematic responses to the concerned environmental parameter. For the above reasons, we are in favour of a transfer function which is calibrated on a regional basis, provided the region is wide enough to fully cover the potential ranges of down-core estimates. Such a regionally calibrated transfer function may perform better than an ocean-wide transfer function in the concerned region. The results of the analysis of core ERDC93P supports this conclusion.

A VIEW FROM THE BOTTOM UP: CONSTRAINTS ON GLACIAL DEEP WATER CIRCULATION AND ALKALINITY FROM BENTHIC FORAMINIFERAL BARIUM DATA

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The distribution of Ba in the oceans resembles that of the deeply-regenerated components alkalinity and silica. As such, Ba can be viewed as a bottom-heavy tracer of oceanic circulation, with its predominant deep-ocean input coming via slowly dissolving sedimentary barite ($BaSO_4$). The biogeochemical controls on Ba are sufficiently different from labile nutrients like phosphate that benthic foraminiferal Ba should not reflect paleoceanographic change in the same way as Cd/Ca and carbon isotopes.

Detailed analysis of GEOSECS data for Ba and alkalinity reveals that these 2 components are linearly correlated throughout the deep waters of the world´s oceans, with a near constant slope of 3 moles of Ba per 2000 equivalents of alkalinity. This relationship apparently reflects similar sites of uptake and regeneration for the particulate carrier phases of Ba and alkalinity, barite and $CaCO_3$, respectively. The striking covariance between alkalinity and Ba in the modern oceans suggests that foram-Ba is the best constraint on circulation induced changes in alkalinity in past oceans.

I am attempting to document changes in the Ba content (and by extension, alkalinity) of Circumpolar Deep Water (CPDW) driven by changes in circulation associated with glacial-interglacial cycles. Ba/Ca results for benthic foraminifera recovered from 6 deep cores lying south of 20°S in the Atlantic, Pacific and Indian Oceans suggest that the Ba content of glacial CPDW was enhanced by 10 to 20% relative to the Holocene. Higher Ba in CPDW during th LGM would be expected as a consequence of the vastly diminished flow of low-Ba NADW into the Southern Ocean.

The Ba results imply a maximum rise in glacial CPDW alkalinity of 25 µequiv/kg. Such a rise, in the absence of an accompanying rise in ΣCO_2, would contribute to lower pCO_2 of upwelled Antarctic waters, as outlined by Broecker and Peng (1989). However, a 25 µequiv/kg rise in CPDW alkalinity can only account for about 1/3rd of the glacial-interglacial pCO_2 change.

PALEOHYDROGRAPHY OF THE BALTIC SINCE THE LAST DEGLACIATION: THE DARSS SILL GATEWAY

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Results from joint Danish and German investigations indicate that the formation of the ice marginal line "G" (Velgaster Staffel) between Falster, Denmark and Fischland, Germany caused the damming of a pre-existing (sub)glacial meltwater discharge system. As the Baltic Ice Lake began to form (around 12,500 yrs. BP), a (glacio) fluvial drainage pattern developed, with a deep and presently buried channel cutting line "G" south of Kadet Channel. Discharge was toward northeast. During the Baltic Ice Lake trangression, an infill by sandy sediments of this channel resulted in the virtual closure of the Darss Sill gateway. Main erosion and deepening of the Kadet Channel began during the Ancylus Lake highstand maximum (around 9,000 yrs. BP) and continued during the following Littorina period.

Present current-induced bedforms, among other 5 m-high sand waves, point to maximm bottom-flow speed on the order of 70-100 cm/s for both in- and outflow.

UPPER PLIOCENE CLIMATE IN NW AFRICA FROM MARINE PALYNOLOGY OF ODP 658

S. Leroy (Institut Géologique, Louvain-la-Neuve, France) and L. Dupont

Pollen-analyses of ODP Site 658 marine core NW Africa (21°N) off Cap Blanc cover 150 m of sediments for the period from 3.6 to 1.5 Ma. The sedimentation rate in this upwelling zone is high. The time scale is provided by forams, nannoflora, palaeomagnetism, $\delta^{18}O$ curves etc. (Tiedemann, 1991), and allows us to immediately plot the results against time.

The Pliocene from 3.6 to 3.3 Ma is characterized by high percentages of *Rhizophora* (mangroves) and a high river influx which decreases afterwards, the transport of the pollen grains is accomplished mainly by the wind.

The Upper Pliocene from 3.3 to 2.5 Ma: there is a many folded event at 3.2 - 3.0 Ma (quick succession of very dry and very humid periods) corresponding to the initiation of Northern Hemisphere glaciations. Afterwards, the climate progressively becomes drier: spectra dominated by Cyperaceae and Poaceae up to 2.7 Ma. Starting at 2.5 Ma., the pollen spectra display regular cycles of vegetation changes. The humid periods (interglacial periods) change to dry periods (glacial periods), with a latitudinal shift of several vegetation zones (successive maxima of *Cyperaceae, Poaceae, Amaranthaceae-Chenopodiaceae, Artemisia, Ephedra*). The transition from interglacial to glacial is progressive. However, the reverse one from glacial to interglacial is abrupt. The Trade Winds strength was changing periodically: they were strong during glacial and weak during interglacial. The changing winds indirectly give an appreciation of the intensity of the upwelling.

This ODP site 658 provides reference curves for the complete Upper Pliocene.

SEDIMENTOLOGICAL INDICATORS OF SEA ICE COVER IN ARCTIC DEEP-SEA SEDIMENTS

T. Letzig (GEOMAR, Univ.of Kiel, Germany), H. Lange, and J. Thiede

Due to the Arctic sediment-laden, sea-ice cover, the Arctic Ocean is a unique sedimentary environment. Apart from consequences for oceanographical processes and marine biological systems, the sediments of the sea ice have great influence on the sedimentary environment. The Arctic sea ice transports mainly fine-grained terrigeneous material (clay and silt) from the Siberian shelves into the central Arctic Ocean and finally into the depositional centers. Seven mio. tons of sediments are annually transported by Arctic sea ice to the Fram Strait, which could account for the entire deep-sea sedimentation in this region.

Sedimentological studies of sea ice sediments show dominance of fine-grained particles and significant clay mineral assemblages with higher smectite values in the sea ice sediments north of 84° N latitude, indicating the Laptev Sea as a possible source area. The Siberian Putorana Mountains are probably responsible for the high input of smectite into the Laptev Sea.

It is necessary to identify sea ice covers in the sedimentary record in order to understand the marine Arctic sedimentary environment. Identification of sea ice-rafted material in the sedimentary record is a complex procedure, as different sedimentological processes like bottom currents (reworking of sediments), gravitive transport and eolian input may diminish the signal data of sea ice-rafted material.

Grain-size analysis by Atterberg methods and sedigraph measurements, determination of mineralogical components in silt fraction, clay-mineral analysis, and especially accumulation rates of fine-grained components from deep-sea sediments of the eastern Arctic Ocean and the Fram Strait will be discussed with regard to implication of sea ice-rafted material. Distinct deglacial phases in the Late Quaternary are indicated by higher sediment accumulation rates of fine grained particles from the Nansen Ridge sedimentary record.

CRETACEOUS-NEOGENE TERRIGENOUS FLUXES IN THE INDIAN OCEAN AND THE NORTH ATLANTIC: A COMPARISON

M.A. Levitan (P.P. Shirshov Institute of Oceanology, Academy of Sciences, Russia)

Cretaceous-Neogene terrigenous fluxes in the Indian Ocean and the North Atlantic were compared using correlation analysis and Q-mode of factor analysis. The Indian Ocean data set includes mass accumulation rates (MAR) of opal-carbonate-free matter (OCFM) for 50 DSDP sites, and the North Atlantic - for 90 DSDP sites. We have received mean OCFM concentrations, mean OCFM MAR and mean weighted OCFM MAR (for the Indian Ocean). All these data characterize the detailed spatial sequence (for instance, Early Paleocene, Late Paleocene, etc) and generalized spatial sequence (for instance, Paleocene, Eocenc, etc).

Mean concentrations of OCFM have no correlation with MAR, and depend on opal-carbonate dilution. Mean OCFM MAR and mean weighted OCFM MAR are in good agreement, but mean MAR are systematically higher. Correlation between generalized sequences for both ocean basins is much better than between detailed sequences. General trends for terrigenous fluxes evolution in the Indian Ocean and the North Atlantic are very similar, and mainly they depend on the global trend of continents denudation and sealevel changes. There is the Eocene anomaly of regional maximal OCFM MAR for the North Atlantic connected with the age of ocean crust northward from Gibbs transform fault zone, and some other causes. Some stages of terrigenous sedimentation are established.

THE REFLECTION OF THE PACIFIC EAST EQUATORIAL ZONE PALEOCEANOGRAPHIC CHANGES IN THE CHEMICAL COMPOSITION OF MIOCENE-QUATERNARY SEDIMENTS (ON ODP LEG 138 DATA)

M.A. Levitan (P.P. Shirshov Institute of Oceanology, Academy of Sciences, Russia)

544 samples from the Miocene-Quaternary sediments of the Pacific east equatorial zone belonging to 11 sites were analysed for $CaCO_3$, $SiO_{2\,biog}$, $C_{org.}$, P_2O_5 and XRF major and minor elements. The average resolution is about 5 m what corresponds from 50,000 to 500,000 years, depending on sedimentation rates.

Correlation analysis and Q-mode of factor analysis led us to obtain the elemental associations connected with biogenous, terrigenous, hydrothermal and diagenetic processes. Mass accumulation rates (MAR) of $CaCO_3$, SiO_2 biog. and opal carbonate-free matter reflect the history of main sedimentation processes during the last 18 Ma. We consider MAR $SiO_{2\,biog.}$ and Ba as excellent semi-quantitative paleoproductivity indicators. Connection between lithology and chemical composition has paramount significance. There are quite definite relationships between MAR of elements (and compounds) and warm-cold episodes during Middle Miocene-Pleistocene. Using MAR of some element indicators, we obtained very clear evidence of the northwest movement of the Pacific plate across the equatorial zone of high productivity. Such dramatic paleoceanographic events as the closure of Panamian seaway and the onset of glaciation in the Northern Hemisphere were reflected in the fluxes of biogenous and terregenous matter. The problem of the surface circulation pattern reflection in the sediments chemical composition is not solved yet.

DIAGENESIS OF ORGANIC MATTER IN SILICEOUS SEDIMENTS FROM THE JAPAN SEA

E. Lichtfouse (Carl-von-Ossietzky-Universität, Oldenburg, Germany) and J. Rullkötter

Miocene to Quaternary deep-sea sediments in the Japan Sea were deposited in a restricted environment leading to the preservation of high amounts of organic carbon averaging 2.5% as indicated by organic geochemical analyses of sediment cores from the Oki Ridge (ODP Site 798) and the Kita-Yamato Trough (ODP Site 799). Despite some facies variations (e.g., intercalation of turbidites), the organic matter is dominantly marine, and diagenesis is controlled mainly by the high geothermal heat flow and the mineral matrix, which is dominantly siliceous with a well-defined opal A/opal Ct/quartz transition between 400 and 600 m depth. Carbonates are only preserved in the shallower sections (<350 m).

Total extracts in the shallower sediments (96-350 m) are dominated by long-chain alkenones from *Prymnesiophytes*. They apparently become bound

to the kerogen at greater depth, and this may be related to carbonate dissolution. Prominent C_{37} and C_{38} *n*-alkanes in the deepest samples studied (about 1000 m) indicate release of previously bound alkenones as saturated hydrocarbons in an advanced stage of diagenesis. *N*-Alkane distributions, in general, show an odd carbon number predominance inherited from terrestrial higher plant waxes in the shallow sediments, but gradually change to an even carbon number predominance with increasing depth, most likely as the result of reductive cleavage or *n*-alkanols or *n*-carboxylic acids, as is typical of sediments lacking clay minerals. Short-chain *n*-alkanes in the deepest samples suggest upward migration of hydrocarbons generated by thermal cracking in sediments exposed to higher thermal stress.

Biological marker ratios show a particularly abrupt change at or below the zone of silica diagenesis which is associated with significant changes in the physical and chemical properties of the sediments (e.g., density, porosity, water content). Besides the Carbon Preference Index this applies to the ratio of 5β, 14α, 17α/5α, 14α, 17α-steranes, which increases to an unusually high value of 45% βαα-isomer. In contrast to this, the ratio of 17α, 21β/17β, 21β-hopanes increases regularly from 6% to 95% αβ-isomer over the depth interval studied.

HIGH-RESOLUTION RECORDS OF LATE QUATERNARY PALEOENVIRONMENTAL CHANGE FROM THE ANOXIC CARIACO BASIN (VENEZUELA)

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Laminated, high deposition rate sediments of the anoxic Cariaco Basin (Venezuela) are an important repository of information on past climates in the tropical North Atlantic. Here we report new faunal and stable isotope data from a high-resolution (<10^2 yr) view of regional events over the last 25,000 years. Seasonal trade wind-induced upwelling along the northern coast of Venezuela today occurs in response to the annual migration of the Intertropical Convergence Zone. Our data show that large changes in the intensity of this upwelling, and hence trade wind strength, occurred during the last deglaciation and throughout the Holocene. Prior to about 12,600 years ago, the Cariaco Basin was partially isolated from the open Caribbean by lowered glacial sea level. Surface productivity was low and oxic conditions were prevalent in the deep basin. At ~12,600 years ago, strong upwelling over the Cariaco Basin began and anoxic conditions developed as rising sea level enhanced connections with the open Caribbean. Foraminiferal abundance records and the accumulation patterns of opal and carbonate indicate that upwelling was strong between 12,600 and 9,500 years ago, and weaker and more variable since then.

Foraminiferal stable isotope data from multiple planktic species record both local (upwelling) and regional signals. $\delta^{18}O$ data from shallow-dwelling *G. ruber* (white) show evidence of fresh-water influence at times of known meltwater discharge into the Gulf of Mexico, while data from *G. bulloides* and *N. dutertrei* record more the effects of upwelling and increased sill depth with rising sea level. Large $\delta^{13}C$ changes (up to 1‰) during the deglaciation correlate well between these species and are remarkably similar in pattern and amplitude to published $\delta^{13}C$ records from the Orca Basin in the Gulf of Mexico. These variations seem to reflect neither upwelling nor meltwater influence, and must instead be indicative of regional changes in the $\delta^{13}C$ of the surface ocean carbon reservoir.

THE VALANGINIAN CARBON ISOTOPE EVENT: A FIRST EPISODE OF GREENHOUSE CLIMATE CONDITIONS DURING THE CRETACEOUS

A. Lini (Geological Institute, ETH-Z, Zürich, Switzerland), H. Weissert, and E. Erba

Lower Cretaceous pelagic carbonates outcropping along the Southern Alps of northern Italy provide a record of Tethyan paleoceanography as well as of low frequency fluctuations in the global carbon cycle. The carbonate C-isotope stratigraphy established in sediments from the Maiolica Formation at seven selected localities in the Southern Alps allows an accurate picture to be drawn of the duration and amplitude of the Valanginian C-isotope event. $\delta^{13}C$ values near 1.25-1.50‰ determined in Berriasian and lower Valanginian sediments (*C. angustiforatus* nannofossil Zone) are replaced by more positive $\delta^{13}C$ values near 3‰ in the late Valanginian (*C. oblongata* nannofossil Zone). The carbonate C-isotope excursion ends in the late Hauterivian (*L. bollii* nannofossil Zone) with values fluctuating around 1.5‰. The carbonate C-isotope excursion is accompanied by a positive excursion in the total organic carbon C-isotope curve.

The Valanginian C-isotope excursion is not limited to the southern Tethys. It correlates with analogous excursions recorded in sediments from the northern Tethyan Shelf, the western North Atlantic (DSDP Sites 534 and 391), Gulf of Mexico (DSDP Site 535) and central Pacific (DSDP Site 167). Furthermore, the correlation between carbonate and total organic carbon C-isotope stratigraphy observed in Tethyan sediments is also recognized at DSDP Site 535.

By analogy with the Aptian stage, also marked by a significant positive C-isotope excursion, the time of positive $\delta^{13}C$ values is regarded as a time of accelerated global carbon cycling. The acceleration of the carbon cycling resulted in increased accumulation rates of organic carbon. High accumulation rates of terrestrial organic carbon and of deep sea siliciclastics suggest that the changes in the global carbon cycle coincided with changes in the global water cycle. These changes reflect a major perturbation of the Valanginian climate which may have been triggered by a tectonically controlled increase in atmospheric CO_2, possibly coupled with a high global sea level, reflecting in this case the first episode of Greenhouse Earth conditions during the Cretaceous.

PALEOCEANOGRAPHY OF THE SPITSBERGEN MARGIN AND DEGLACIATION HISTORY OF ITS ICE CAP

J. Lloyd (Geology and Geophysics, Univ. of Edinburgh, Scotland), D. Kroon, and G. Boulton

Sedimentary architecture and faunal composition of cores taken from the high latitudinal continental margin of Spitsbergen are being studied. From the sedimentology and faunal content we intend to deduce palaeoceanographical changes and ice oscillations on a glacial-interglacial scale. The cores were taken during an expedition of the Geological Survey of the Netherlands, with the survey vessel Hr. Ms. Tydeman of the Hydrographic Survey of the Netherlands.

Stratigraphic control for these cores has been attained through radiocarbon dating, and by comparison of the oxygen isotope stratigraphy with the stacked composite Norwegian Sea record of Labeyrie (1991). The combination of the isotopic record of two cores studied, PCM5 and PCM7, gives a complete record as far back as oxygen isotope stage 6. Core PCM7 shows a very detailed record of the last deglaciation, the sedimentation rate over this period is in excess of 30cm/1000yrs. Three major warming phases can be identified rather than the two identified from most other areas (TIA and TIB of Fairbanks (1989), and Sarnthein). Termination II between isotope stages 6 and 5, as seen in core PCM5, also exibits a three step warming pattern.

Sedimentological data from X-rays and particle size analysis indicates periods of intense ice melting at the end of glacials and during interglacials, this acts to dilute the foraminiferal productivity record. Thus the absolute abundance of foraminifera is often greater during cold periods and dramatically reduced during warm periods.

Pulses of Atlantic water input can be identified from the benthic foraminiferal record, these pulses pre-date initial melting and may be associated with melting of the Spitsbergen ice cap.

POSTGLACIAL PLANKTON AND TEPHRA EVENTS AT THE CONTINENTAL MARGIN OFF NORTHERN NORWAY

S. Locker (Special Research Project 313, Kiel, Germany)

Two sediment cores recovered from the high sedimentation area west of Gamlembanken off northern Norway (67°N-08°E, 1000 m water depth) provided a composite section containing 912 cm of postglacial sediments. These sediments have been investigated for plankton and tephra particles.

Isotopical, sedimentological and planktological data enable one to describe the deglaciation process at the continental margin off northern Norway in great detail. The deglaciation during Termination Ia (14.8-13.6 ka) was accompanied by a distinct sedimentation pulse. But plankton groups such as diatoms and radiolarians first appeared at about 13.3 ka, indicating that the Norwegian Current was fully established only from this date. Late Pleistocene planktoncoenoses existed in low density, and contained a high percentage of cool-adapted species. They persisted in low abundance until the Younger Dryas, when siliceous and calcareous plankton drastically declined just before the Vedde-ash event (10.6 ka). During Termination Ib (10.4-9.1 ka), diatoms and coccolithophorids developed successively strong acme phases, whereas radiolarians increased more continously in abundance and diversity. In late Holocene time radiolarians reached a maximum in productivity, as indicated by 13,400 skeletons/gram sediment.

GLACIAL-INTERGLACIAL CHANGES IN THE UPPER OCEAN RECORDED BY DEEP-LIVING PLANKTONIC FORAMINIFERA

G.P. Lohmann (Woods Hole Oceanographic Institution, Woods hole, MA , USA)

The deep-living species *G. truncatulinoides* calcifies its shells as it sinks from surface waters through the upper 1 km of the water column, recording properties of the upper ocean in several different ways: (1) $\delta^{18}O$ increases as shells grow and sink through the main thermocline. The $\delta^{18}O$ difference between juveniles and adults reflects the magnitude of the temperature gradient between the surface and -500m. Today these gradients are greatest at the equator where cold deep waters are upwelled toward warm surface waters and

least in the subtropics where warm surface waters are subducted at convergences. During the last glacial maximum (LGM) these gradients increased in the subtropics and decreased at the equator. (2) Regional differences in adult *G. truncatulinoides'* $\delta^{18}O$ record regional temperature-$\delta^{18}O$ differences at -500m. Today the lightest $\delta^{18}O$ are from the subtropical gyres and the heaviest are from the equator reflecting the contrast between subducted subtropical surface waters and upwelled equatorial deep waters. During the LGM this contrast was less. (3) Shell crusting is triggered when shells encounter cold water, so the size at which they crust depends on the depth to the thermocline and regional differences in size at crusting reflect regional differences in themocline depth. Today crusting occurs earliest where the thermocline is shallowest (equatorial Atlantic, western Mediterranean) and latest where the thermocline is deepest (subtropical gyres). During the LGM *G. truncatulinoides* crusted at larger sizes at the equator and smaller sizes in the subtropics, implying that the thermocline was deeper at the equator and shallower in the subtropics. (4) $\delta^{13}C$ of crusted *G. truncatulinoides* is similar to that of *Cibicidoides* and, therefore, similar to that of seawater ΣCO_2. Today the $\delta^{13}C$ of crusted adult *G. truncatulinoides* are lightest at the equator where old deep water is upwelled. In contrast, their $\delta^{13}C$ during the LGM decreased from a maximum in the North Atlantic to a minimum in the South Atlantic.

During the LGM the regional $\delta^{18}O$-$\delta^{13}C$ gradients and thermocline geometry reconstructed from deep-living planktonic foraminifera show that the differences between equator and subtropics were reduced. This implies either that the wind forcing driving these differences was weaker or that the upper ocean density gradient on which that forcing operates was stronger.

THE ICE CORE RECORD OF GLOBAL CHANGE

C. Lorius (Lab de Glaciologie et Geophysique de l'Environnement, CNRS, Grenoble, France), J. Jouzel, and D. Raynaud

Ice cores from polar ice sheets provide multiproxy records of climate and atmospheric related parameters, many of them being of hemispherical or even global significance. The history of ice core records started only 25 years ago, and is based on a very few drilled holes, extending so far over the last 160,000 years.

In favorable conditions, counting of annual layers allows absolute dating back to 50,000 years. More generally, beyond the end of the last ice age, ice cores are dated by ice dynamics models. Specific climatic features or events, such as ^{10}Be peaks around 35 kyr BP, have been used to correlate records for various sites within polar ice sheets.

The analysis of nitrates, sulfates, and heavy metals such as lead in Greenland snows allows man's impact on the atmospheric chemistry in the Northern Hemisphere to be determined. Air bubbles trapped in Antarctic ice show changes in the concentration of greenhouse gases (CO_2, CH_4, N_2O) since pre-industrial times, which reflect a global impact, and is likely to be important for future climate.

There are several time periods when interpretation of information gained from the ice would particularly benefit from a marine perspective input. In Antarctica the warmest part of the current interglacial was at the beginning of the Holocene. In Greenland, the last deglaciation was interrupted by a series of mild and cold (e.g., Younger Dryas) events; similar features are also apparent in Antarctic data, but with a smaller amplitude which reflects their likely Northern

Atlantic origin. During the late-glacial, mild interstadials occur irregularly in Greenland ice, but have not been detected in Antarctica.

Ice cores have recorded glacial-interglacial temperature changes with cold stages associated with lower snow accumulation and high concentration of aerosols from marine and continental sources. The 160,000 years long Vostok isotope temperature record shows a close association with greenhouse gas concentrations; these gases have likely played an important role in the amplitude of past temperature changes, giving insight to future climate scenarios. This record has recently been extended to fully cover the penultimate glacial period.

The glaciological dating of this record has been refined to take into account snow accumulation changes with space and time. Time series results do agree with the SPECMAP marine chronology down to 110 kyr BP, but the previous interglacial duration appears to be much longer in the ice record. The marine and ice records can tentatively be correlated within geographical areas by using atmospheric dust fallout in both types of sediments. A more global comparison is possible by using $^{18}O/^{18}O$ measurements in marine sediments and in gas inclosures in ice as they appear to both reflect ice volume changes. A common temporal framework shows that the Southern Ocean SST and the Vostok climatic record have a high degree of similarity. Available data also suggest that during the penultimate deglaciation the greenhouse gas-forcing was ahead of the forcing related to the retreating ice sheets.

The current GRIP and GISP deep drilling efforts in Greenland will hopefully cover two climatic cycles, and there are plans for further deep drilling both in west and east Antarctica.

Much more information can be gained for explaining climatic and atmospheric composition changes, from the comparison of ice and marine records. Discussion of relevant complementary drilling sites would also be of mutual interest.

PLIOCENE TO EARLY PLEISTOCENE ASTRONOMICALLY FORCED SEA SURFACE PRODUCTIVITY AND TEMPERATURE VARIATIONS IN THE MEDITERRANEAN

L.J. Lourens (Institute of Earth Sciences, Utrecht, The Netherlands), A. Antonarakou, F.J. Hilgen, C. Vergnaud-Grazzini, and W.J. Zachariasse

High resolution sea surface productivity (SSP) and sea-surface temperature (SST) proxy records are presented for the entire Pliocene and early Pleistocene. These records are based on a-priori assumptions of selected eutrophic and temperature-sensitive planktonic foraminiferal species using modern habitat characteristics. Spectral analysis revealed significant peaks in the orbital frequency bands of the spectrum suggesting that variations in sea surface productivity and temperature are controlled by the quasi-periodic variations in the Earth´s orbit.

Precession-forced (23 kyr) variations are reflected primarily in sea-surface productivity and to a lesser degree in sea-surface temperature. Maxima in SSP and SST in this frequency band correspond to minimum values in the precession index and occur at times of deposition of both grey marly layers and sapropels. Precession-forced variations in sea surface temperature are not related to glacial cycles since this frequency component is almost completely absent in ice volume proxy records for this time interval. Presumably, sapropel-bound sea-surface temperature maxima reflect periods of maximum northern Hemisphere summer insolation. Precession (23 kyr) filtered components extracted from the SSP and SST proxy records show an excellent resemblance with the 23 kyr component from the precession cycle and its modulation by the 400 kyr component of eccentricity.

Obliquity-forced (41 kyr) variations are reflected in sea-surface temperature and not in sea-surface productivity. Between 1.2 and 2.8 Ma these temperature fluctuations correspond with the oxygen isotope stages recorded at the North Atlantic DSDP Site 607, indicating that they are controlled by glacial cycles. The presence of the same frequency component between 3.2 and 4.0 Ma indicates that during this interval sea-surface temperature variations were also influenced by obliquity, suggesting that Pliocene glacial cycles may well have occurred before 2.8 Ma.

PLANKTONIC FORAMINIFERA DISOLUTION IN THE TROPICAL ATLANTIC

N.P. Lukashina, (P.P. Shirshov Institute of Oceanology, Academy of Sciences, Moscow, Russia)

Planktonic foraminifera have been studied in 37 samples of recent bottom sediments from a depth range of 2,020-6,120m throughout a latitudinal profile of the tropical Atlantic.

Globigerinoides ruber appears to be the most widely spread species in sediments of the North American basin, and constitutes 60-80% in tanatocoenosis. The value of this species at all depths remains rather constant, including the carbonaceous compensation depth, which is located at 5,500m in the southern-most area of the basin; northwards it reaches 5,700 m. Concentration of intact shells of *G. ruber* is high, even in 90% dissolved tanatocoenosis. The species, *Globigerinoides trilobus*, which is the most abundant at a depth of 5,500m, *Globigerinoides sacculiter* and *Globigerinoides conglobatus*, which are accumulated at depths of ~ 5,100 m, are dissolution-resistant.

In the eastern part of the region, at the Mid-Atlantic Ridge slope and in the adjacent Canary basin, the concentration of *G. ruber* is a little lower (40-70%). The value of this species gradually decreases with dissolution, but it occurs towards ciritcal depth at 5,100m in considerable quality. In highly dissolved tanatocoenosis, dissolution-resistant species are found (*Glodoguadrina dutertrey, Globorotalia tumida*, and *Globorotalia crassaformis)*.

Many scientists consider *G. ruber* one of the most easily dissolved species. In this respect Ruddiman and Heezen (1967) noted that dissolution of this species in the equatorial Atlantic begins at 4,000m. Our data indicate that intact shells of *G. ruber* are found much deeper in the tropical Atlantic. This is connected with the fact that properties of Antarctic bottom water, agressive to calcium carbonate, transform as they pass from the origination region, and dissolution of low magnesian planktonic foraminifera occurs at greater depths. Also, high concentration of *G. ruber* in the western part of the investigated area could be connected with its high dominance in tanatocoenosis, caused by high salinity of the surface water.

THE STABLE ISOTOPIC COMPOSITION OF GLACIAL ANTARCTIC INTERMEDIATE WATER

J. Lynch-Stieglitz (Lamont-Doherty Geological Obervatory, Palisades, NY, USA), R. Fairbanks, and C. Charles

Antarctic Intermediate Water (AAIW) is the predominant intermediate depth water mass in today's ocean. It derives its chemical and physical properties from the Southern Ocean surface waters from which it forms. The carbon and nutrient content of this water mass as it leaves the surface near the polar front will determine its role in the global carbon cycle. AAIW also plays and important role in the structure of the ocean, as its temperature and salinity determine the depth of the main thermocline in much of the Southern Hemisphere, and in the general circulation of the ocean via its northward transport of cool, fresh water.

We have obtained a vertical profile of carbon and oxygen isotopes at intermediate depths which record the properties of AAIW through the last glacial maximum. These records were obtained from benthic foraminifera in sediment cores collected off South Australia. The depth of the AAIW core in the profile can be determined from the oxygen isotopes which reflect the ocean temperature structure. Preliminary results show that the $\delta^{13}C$ of glacial AAIW was not significantly different from that of today. As AAIW was likely to have been an important intermediate depth water mass during glacial times, these results along with evidence for the lowering of deep water $\delta^{13}C$ are consistent with the observations of increased intermediate to deep $\delta^{13}C$ gradients in the glacial ocean. As the composition of AAIW should reflect the Southern Ocean surface water from which it forms, the unchanged glacial AAIW $\delta^{13}C$ seemingly contradicts the significantly lower glacial $\delta^{13}C$ of Southern Ocean surface waters inferred from planktonic foraminifera.

The $\delta^{13}C$ of atmospheric CO_2 is determined by the $\delta^{13}C$ of dissolved carbon in the surface ocean, and the degree of isotopic equilibration between the atmosphere and the warm and cold surface ocean. We evaluate the conflicting evidence for the $\delta^{13}C$ of Southern Ocean surface waters in light of the recent measurements of the $\delta^{13}C$ of the glacial atmosphere (Marino et al., 1992; Leuenberger et al., 1992).

PALYNOMORPH RECORDS OF THE LAST GLACIAL-INTERGLACIAL CYCLE IN THE EASTERN EQUATORIAL ATLANTIC

F. Marret (Institute of Palynology and Quaternary Sciences,Göttingen, Germany)

The palynological analysis of two marine piston cores recovered from the Gulf of Guinea and correlated with isotope stratigraphy ($\delta^{18}O$), provides continuous paleoclimatic and paleoceanographical information for the last 130,000 years.

The rain forest, the mangrove and the afromontane vegetation show fluctuations during glacials and interglacials. The dominance of *Podocarpus* in the sequences suggests the extension of this afromontane taxon towards lower altitudes during stages 6, 5 (5e) and 2. Nowadays, this conifer tree is restricted in West Africa to the Highlands of Cameroon. High pollen influx during glacial stages (6 and 2) reflects intensified atmospheric circulation.

In core M 16867-2, the dinoflagellate cyst record is characterized by an outer-neritic association whereas an oceanic association prevails in core M 16772-2. However, in both sequences, temperate species are dominant during stages 6 and 2 and are replaced by tropical species during interglacial periods. High concentrations during glacial stages are correlated with an increase of the productivity induced by an intensification of the surface oceanic circulation (upwelling).

The reconstruction of paleotemperatures and paleosalinities from the dinoflagellate cyst record show fluctuations of those hydrological parameters correlated with the $\delta^{18}O$ curve. Seasonality and salinity are higher during glacial stages: paleotemperatures show more variation during austral winter than during summer.

TEMPERATURE AND SALINITY HISTORY OF THE LAST DEGLACIATION AND HEINRICH ICE-RAFTING EVENTS I TO IV IN THE NE ATLANTIC

M.A. Maslin (Godwin Laboratory, Univ. of Cambridge, UK), N.J. Shackleton, J.-C. Duplessy, and M. Arnold

Palaeotemperatures were estimated for the last 40 kyr in BOFS core 5K (50°41.1'N, 21°51.9'W, water depth 3547m: time resolution several hundred years) using the CLIMAP FA20 transfer function equation. Salinity was calculated from the $\delta^{18}O$ records of *N. pachyderma* (L) and *G. bulloides* using the method developed by Duplessy et al. (1992). The two-stage deglaciation is clearly defined by the $\delta^{18}O$ records, whereas the Heinrich ice-rafting events 1 to 4 have been identified from peaks in both the lithic composition of the >150 μm size fraction and in the whole core magnetic susceptibility record. These events have been dated using an age model based on 12 AMS ^{14}C dates and two ash layers, Vedde and Saksunarvatn. Associated with Heinrich events 2,3 and 4 are colder temperatures and lower salinity, suggesting increases in polarwater contribution to the NE Atlantic at 50°N and significant meltwater and ice-rafting detritus input from icebergs. Heinrich event 1 is shown to be synchronous with Termination 1A and is associated with increasing SSTs and low salinities, suggesting declining polar water influence at this site but significant meltwater and detrital input from icebergs. We conclude that from such high resolution work it is possible to identify short ice-rafting events and to document their effect on the sea-surface conditions.

LATE QUATERNARY PALAEOCEANOGRAPHIC RECONSTRUCTION OF THE SOUTHERN TASMAN SEA, SOUTHWEST PACIFIC

J.I. Martínez (Dept. of Geology, The Australian National University, Canberra), S. Nees, P. De Deckker, and M.A. Ayress

Core E36-23 (water depth: 2,482 m) is situated on the East Tasman Plateau, in the southern part of the Tasman Sea, at the Subtropical Convergence. The core is located within the deep water mass, presently situated below a Deep Oxygen Minimum zone (~500 m thick) that separates the deep water from the AAIW.
The 5.5 m long core was examined for planktic and benthic foraminifers, and ostracods to reconstruct the history of the water masses over the East Tasman Plateau for the last 400,000 years.

Changes in the percentage of *G. truncatulinoides* provide a record of palaeoclimatic fluctuations. The latitudinal migration of the Subtropical Convergence Zone, between glacial and interglacial stages, is documented

through variations in the percentages of cold subtropical and subantarctic planktic foraminiferal species. Changes in the structure of the thermocline/mixed layer have also been detected. Dissolution of planktic foraminifers during glacial stages reflects the influence of the corrosive nature of the Antarctic Bottom Water in the southwest Pacific, as recorded in the Atlantic.

The repeated occurrence of a distinct benthic foraminifer assemblage characteristic of the deep water indicates that the latter water mass frequently persisted over the studied site during the last 400 ky. Correlation with modern benthic foraminiferal assemblages in the Tasman Sea indicate strong similarities with faunal associations found at a 3,000 m water depth on the Lord Howe Rise.

Peaks of abundance of ostracod valves correspond with levels of low foraminiferal fragmentation, thus indicating the susceptibility of ostracods to dissolution. Despite low abundances of ostracods, there is indication that ostracod species composition is related to varying bottom water conditions.

LATE PLEISTOCENE DISSOLUTION PATTERNS IN THE SOUTH WEST PACIFIC

J.I. Martínez (Dept. of Geology, The Australian National University, Canberra)

Comparison of dissolution foraminiferal records (fragmentation percentage, dissolution indices, benthic percentage and $CaCO_3$ content) from cores taken in water depths varying from 1000 to 3000 m (above the present-day lysocline) along a north-south transect connecting Vanuatu with New Zealand (ODP 828A, ODP 832A, RC12-113, DSDP 591, DSDP 593 and E36-23), reveals changes in the nature of the lysocline related to the action of intermediate to deep waters. Two different dissolution patterns are detected: 1) a typical example of the "Pacific type" near Vanuatu (ODP cores 828A and 832A), where dissolution cycles occur during times of glacial ice-growth (resembling closely the stable isotope record, but lagging glacial terminations by approximately 8 ky); and 2) a typical example of "Atlantic type" recognized in the Tasman Sea record (E36-23) where dissolution cycles occur mainly during glacial maxima. A "global" dissolution pulse around the isotope stage 4/5 boundary occurs in most of the cores. The Lord Howe Rise appears to act as the boundary between two dissolution regimes, thus reflecting different patterns of deep-water circulation. Nutrient-depleted North Pacific Deep Water and corrosive Antarctic bottom water/circumpolar deep water were active during glacial maxima, and corrosive North Atlantic Deep Water during interglacial to glacial transitions. The northward shift of the Subtropical Convergence Zone in the southern Tasman Sea during glacial stages could operate as an additional CO_2 sink.

THE PECULIARITIES OF GEOLOGY AND QUATERNARY PALAEOGEOGRAPHY OF THE SHELF OF FRANZ JOSEF LAND

G.G. Matishov (Murmansk Marine Biological Institute, Academy of Science, Russia)

New data on Quaternary geology and geomorphology of Franz Josef Land and the adjacent shelf were received as a result of summer (1991) field observations on the research vessel the "Dalnie Zelentsy." The detailed

bathymetry map (1:500,000) for the region of archipelago was drawn up. The original schemes of glaciation and deglaciation of the northeastern part of the Barents Sea have been received.

CYCLIC CARBONATE FLUCTUATIONS IN THE EARLY CRETACEOUS TETHYS - PALEOCEANOGRAPHIC CONSIDERATIONS

H. Mayer (Scripps Institution of Oceanography, UCSD, La Jolla, CA, USA)

Cyclic variations of carbonate content in the pelagic nannofossil limestones of Early Cretaceous Maiolica/Biancone formation of the Southern Alps (Italy) are demonstrated with the case study of the Cismon section. The amplitudes of the variations are rather small between 87% and 97%. Magnetic susceptibility measurements performed on splits of the same samples are highly negative correlated to carbonate content except for two narrow intervals in the section where extreme susceptibility values are observed. Fourier analysis of the carbonate series yields prominent amplitude peaks at 98 cm, 41 cm and 20 cm thickness periods. Although conversion of thickness periods to time periods is hampered by poor time control, the ratios between these cycle periods are almost identical to ratios between the dominant Milankovitch cycles of 100 kyr, 41 kyr and 21 kyr. Assuming that the cycles detected in the Maiolica represent Milankovitch cycles of climate variations in the Cretaceous recorded in pelagic sediments, some paleoceanographic considerations regarding variations of carbonate production, of carbonate dissolution and of terrigenous input of the non-carbonate fraction are presented.

3-D VISUALIZATION OF EVOLUTIONARY SPECTRA OF LEG 138 CARBONATE RECORDS

L.A. Mayer (Univ. of New Brunswick, Fredericton, Canada), N.J. Shackleton, T. Hagelberg, N. Pisias, C. Ware, K. Marinelli, and the ODP Leg 138 Shipboard Scientific Party

Scientists on board ODP Leg 138 modified standard shipboard computing procedures so as to allow the near real-time acquisition and comparison of several continuous core logging systems (GRAPE, susceptibility, and velocity). These records were used to modify the drilling strategy to ensure proper offset between multiple holes, to splice records from multiple holes together into a complete section, and to design an efficient high-resolution sampling strategy (see Hagelberg et al. poster). The GRAPE density records are particularly useful in that they can be transformed to % carbonate and thus produce a continuous, and extremely high-resolution, record of an important component of the ocean system. These records show remarkable site-to-site correlation and have been tuned to the insolation record at 65°N in order to produce a high-resolution time scale to at least 6 Ma (see Shackleton et al., posters). We have taken these tuned carbonate records and generated evolutionary spectra. These plots are a series of spectra calculated over a 900,000 year window that is shifted in 10% (90,000 years) increments. The spectra are variance conserving, and thus the relative amplitude of the response of the carbonate system to orbital forcing can be compared through time. The evolutionary spectra of the Leg 138 sites have some features that are similar (indicating global responses) and some features that differ (indicating more local

responses). In order to better explore the nature of the temporal response of the carbonate system to orbital forcing, the revolutionary spectra are transformed into a 3-D array and formed into a digital terrain model. We then take advantage of our newly developed six-dimensional mouse (BAT) and, in real-time, fly through the evolutionary spectra. A video of these flights will be presented.

THE RECORD OF BOTTOM CURRENT SPEEDS IN DEEP-SEA SEDIMENTS

I.N. McCave (Dept. of Earth Sciences, Univ. of Cambridge, UK)

The depositional regime, particularly the current speed, exerts a strong control on the characteristics of the deposit. The bottom boundary layer filters aspects of the input signal from vertical settling and horizontal flux in nepheloid layers. Fabric is dominated by bioturbation so currents cannot be inferred from sedimentary structures. Deposition is permitted when for a particle (usually aggregate) settling velocity w_s the bottom stress is below a critical value T_c. Under high stress deposition of clay is suppressed and a coarser deposit forms. Deposition from suspension is dominant with little bed-load transport. All deep-sea currents fluctuate and regions of large speed variation in days to weeks are called "stormy". We cannot yet distinguish regions with different time scales of fluctuation by their sediments alone. Nice modern regional examples of high speed are the Nova Scotian Rise, northeastern U.S.A. margin and the Argentine Basin. The parameters used to delineate the currents there were silt mode size and peak height and terrigenous silt mean size. Wide spectrum grain-size analyses and experimental data show that fine silt ($\delta < 10$ µm) behaves in a cohesive manner similar to clay while coarse silt ($\delta = 10$ to 63 µm) is nearly non-cohesive. Therefore, the percentage of the <63 µm fraction that is coarse silt is a useful parameter. The coarse fraction >63 µm is almost always foraminiferal, ice-rafted or in a gravity flow deposit. There is little quartz sand transport by deep-sea currents because speeds (at 1 mab) greater than 30 cm/s are required; these are rare and would not yield much bed-load flux.

A difficulty with evaluation of current speeds from sediment size is the influence of provenance. A record from the S. Brazil Basin, showing size fluctuations at ~40 and ~20 ka at a site far from source, is argued to demonstrate current speed variation. The delivery from continents to the continental rise involves erosion and mixing of sediment populations so that a clear glacial/interglacial signal is unlikely from gravity flows. It does arise from ice-rafting, however, and the extraction of signals from sediments affected by ice-rafting currents, and biological productivity is difficult. Recent attempts to isolate current signals in mid- to late-Pleistocene sediments from Vema Channel, the eastern USA margin, and N.E. Atlantic drifts will be discussed. The picture is not clearly one of decreased glacial current speeds. The relationship between local current speed and the vigor of ocean circulation is also debatable.

LGM AND HOLOCENE $\delta^{13}C$ PROFILES FROM THE INDIAN OCEAN OFF WESTERN AUSTRALIA

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Glacial-to-Holocene $\delta^{13}C$ results from the benthic foraminifera *C. wuellerstorfi* suggest only a modest net transfer of nutrients from intermediate to deep waters in the glacial southern Indian Ocean. We present stable isotope data from four cores from the Exmouth Plateau (≈ 19°S, 113°E) and two cores from Perth Basin (≈ 27°S, 111°E). These cores range in depth from 950 m (within the oxygen minimum in the modern Indian Ocean) to 2750 m, and extend back through isotope Stage 5e.

Stage 1, *C. wuellerstorfi*, have $\delta^{13}C$ values 0.2-0.3‰ higher than nearby GEOSECS $\delta^{13}C$ (ΣCO_2) values, but show a similar vertical profile; $\delta^{13}C$ values show little change from the core-top values, suggesting that lower nutrient concentrations at this depth in the glacial southern Indian Ocean offset the global average ≈0.3 ‰ $\delta^{13}C$ decrease in the glacial ocean. In contrast, the LGM $\delta^{13}C$ values of cores from 2 to 3 km are ≈0.4 ‰ lower than the corresponding core-top values.

Although these results are consistent with glacial nutrient "downshifting," we do not observe either the strong intermediate depth $\delta^{13}C$ enrichment or the strong deep-water $\delta^{13}C$ depletion previously reported of the northeastern Indian Ocean.

WIND-CONTROLLED SPATIAL AND TEMPORAL THERMOCLINE/NUTRICLINE/ PRODUCTIVITY VARIATION IN THE EQUATORIAL ATLANTIC: 0-200 KA

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Climate modulation of the ratio of zonal to meridional velocity components of the trade winds controls equatorial surface water dynamics at all periods from <1 day to> 400 ka. For orbital periods of insolation forcing the maxima in trade wind zonality occurs at perihelion in boreal winter. This produces maxima in horizontal and vertical surface-water velocity, thermocline and nutricline gradients, and primary productivity and minima in surface water temperature. Perihelion in boreal summer maximizes the monsoonal (meridional) component to produce the opposite effects. Biotic proxies, e.g., the coccolithophorid, *Florispharea profunda*, estimated SST, organic carbon, opaline silica, etc. monitor local variation of these wind-controlled phenomena. The relation of *F. profunda* to thermocline gradient has been established with living material from transects across the South Equatorial Current.

Despite the major climate/ocean changes of the glacial-interglacial cycles, the geometry of equatorial surface oceanography is stable. Equatorial divergence remains centered on 2°S, 10°W, a nodal point, where thermocline and nutricline maintain the highest gradients and thus primary productivity through all climate states. At this node cross-spectral analysis of *F. profunda* to estimated water temperature demonstrates strong correlation, mean value >0.7, and at the dominant 23 ky period the signals are coherent, mean k>0.9 and in phase. North and South of this node, the intensity of divergence and the gradients of both thermocline and nutricline decreases.

All signals are dominated by precession (23 ky period). Response difference is shown by lack of coherence between 23 ky signals at the node and those north or south of the node which are coherent and in phase. At the nodal point, temporal oscillation occurs such that while having the strongest precessional response (total variance >50% at 23 ky) the amplitude has greater statistical variability and thermocline response lags that of surface water temperature.

UNRAVELING THE INFLUENCE OF PALEOCEANOGRAPHIC, SEA-LEVEL AND TECTONIC CONTROLS ON LONG-TERM CARBONATE PLATFORM EVOLUTION: RESULTS FROM ODP LEG 133 ON NE AUSTRALIAN MARGIN

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The processes controlling initiation and long-term evolution of carbonate platforms remain controversial. Even more debatable are the factors terminating platform growth. Once initiated, carbonate platforms are dynamic systems with potential growth rates faster than most geological processes. A healthy platform with a high-growth potential should be able to compete constructively against destructive forces. Why then do carbonate platforms drown? Major objectives of ODP Leg 133 on the NE-Australian margin addressed problems concerning platform initiation, growth and demise with the study of the temporal and spatial evolution of the Queensland (QP) and Marion plateaus and the Great Barrier Reef (GBR).

During ODP Leg 133, 16 sites were drilled along two seismically imaged transects across the platform margins, down the slopes and into adjacent basins. With this drilling strategy, it was possible to sample and date the environmentally characteristic lithofacies comprising the seismic sequences. For example, a Middle/Late Miocene sea-level fall can be traced as an exposure horizon on the margins, an erosion surface on the slopes and gravity deposits in the basin.

To delineate the factors controlling the evolution of the platforms, facies analyses combined with an evaluation of depth-dependent benthic foraminiferal assemblages provided information on changing water depth, as an indicator of platform subsidence and sea level, whereas paleoceanographic changes were defined by chemo- and biostratigraphic analyses. Leg 133 data demonstrate the paleoceanographic control on platform development. Major changes in circulation patterns with warmer surface waters can account for the sudden appearance of tropical reefs on the early Miocene QP and Pleistocene GBR. Cooler waters in the late Miocene decimated the QP reefs. These conditions combined with continued subsidence brought an ailing QP into water depths from which it could not be rejuvenated. However, isolated QP reefs did live on to serve as sheltered, off-shore cradles to fertilize a GBR renewal with each Pleistocene sea-level rise.

HOLOCENE SEA-LEVEL RISE, BERMUDA

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The Bermuda seamount is extinct since 28 My. The crust around Bermuda is tectonically stable. Contortion by elastic bulging by changing polar ice loads is minimal, and water load on the crust should be negligable compared with shelf areas. Therefore, "The curve of relative sea level in Bermuda vs. time must be an indicator of 'absolute sea-levels,' if that term has any meaning at all," (Vacher, 1973).

Subbottom profiling and coring in North Lagoon, inshore waters and marshes of Bermuda has provided a detailed curve of Holocene sea level that reaches back 11,800 years and down 33.3 m. Radiocarbon dates from near-bedrock peats reveal a very regular, parabolic sea-level curve. Sea level rose at 5 m/1,000 y at the beginning and slowed down to zero within the last few thousand years. The curve is closely modelled by the parabola:

$\text{level} = \text{age}^2 / 5$

$\text{age} = \sqrt{5} \times \text{level}$ age: ky; level: meters

with a well-documented excursion around 8,880 years when sea level rose with a jump of 3-4 m that can tentatively be attributed to an ice surge.

Bermuda may now be taken as a Holocene tide gauge, and crustal deformations in less stable regions measured against this standard.

CHEMISTRY OF A RECENT (0-1,700 YRS BP) MN/FE-COATED PTEROPOD PAVEMENT IN THE N.E. ATLANTIC OCEAN: CHEMICAL SIGNALS FOR PRESERVATION VS. DISSOLUTION

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Preservation of (up to 13 cm thick) pteropod pavements at present takes place in the N.E. Atlantic Ocean at water depths between 2700 and 3200 m. The sedimentary environment is one of moderate winnowing, keeping thearagonitic skeletons at the surface.

All pteropods are Mn-Fe stained to coated; the intensity of staining increases with age, and correlates with increasing concentrations of Mn, Co, As, Fe, Th and LREE.

Four different stages of staining intensity can be recognized; they represent four major periods of maximum preservation between 1740 and 1700, 1470 and 1140, 810 and 670, and between 400 years ago and the Present. In between periods of enhanced dissolution and/or oxidation of organic matter caused syn-sedimentary element reorganization.

Dissolution results in Fe- (plus Th, plus As) depletion relative to Mn, as Fe preferentially re-adsorbs onto clay particles, while Mn (plus Co, plus Ce) may readsorb onto nearby Mn-Fe oxyhydroxides. On the other hand, fractionation due to differences in redox behaviour may result in Mn depletion relative to Fe. Maximum Fe concentrations and Al to non-carbonate ratios are indicative for preservation at times of non-depostition.

GLACIOLOGY AND OCEANOGRAPHY IN THE SOUTHERN WEDDELL SEA SINCE THE LAST GLACIAL MAXIMUM

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During several expeditions with R.V. "Polarstern" since 1982, sediment sampling and sub-bottom profiling were carried out in the southern Weddell Sea. The sediments recovered represent the period of deposition from the last glacial maximum until recent time. This poster presents a summary of the main interpretations made from this material.

The continental ice sheet advanced to the shelf edge and grounded on the sea-floor presumably later than 31,000 y.B.P. The ice movement was linked with erosion of shelf sediments and a very high sediment supply to the upper continental slope, entailing sediment gravity flows at the slope. Above the lower slope and continental rise, a very dense sea-ice coverage occurred, whereas above the upper continental slope, a < 50 km broad coastal polynya existed at least periodically. Intense sea-ice formation in the polynya probably led to the development of a high salinity and, consequently, dense water mass, which flowed as a stream near bottom across the continental slope into the deep sea, possibly contributing to bottom water formation.

During the period 14,000 to 13,000 y.B.P., the ice masses started to retreat from the outer continental shelf predominantly due to calving processes. The sea-ice coverage decreased and, simultaneously, the formation of the high-salinity dense bottom water above the upper slope ceased.

The formation of Ice Shelf Water (ISW), which recently contributes to bottom water formation, started beneath the Filchner-Ronne Ice Shelf somewhat later than 12,000 y.B.P. Primarily, the ISW streamed with lower velocities than those of today across the continental slope into the deep sea. At 7,500 y.B.P., the grounding line of the ice masses had retreated > 400 km to the south.

A progressive retreat by additional 200 to 300 km probably led to the development of an open water column beneath the ice south of Berkner Island at about 4,000 y.B.P. This, in turn, may have led to an additional ISW, which had formed beneath the Ronne Ice Shelf, to flow towards the Filchner Ice Shelf. As a result, increased flow of ISW took place across the shelf edge and at the upper continental slope towards the west.

ROCK MAGNETIC PROPERTIES AS RECORDS OF PALEOCLIMATE IN OCEANIC CORES OF THE WESTERN EQUATORIAL INDIAN OCEAN

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Rock magnetic parameters (low-field magnetic susceptibility, natural and anhysteretic remnant magnetizations, etc.) of wet marine sediments reflect downcore changes in the concentration, grain-size and composition of magnetic minerals which are, in turn, a function of regional and/or global climatic changes. So far, studies performed in the equatorial and northern Atlantic reveal high magnetic concentrations for glacial horizons (associated with low carbonate productivity), while interglacial zones are characterized by lower concentrations of magnetic minerals.

The downcore variations of the magnetic properties have been measured in three marine cores distributed within the Somali Basin (between latitudes 0°

and 3°N). The correlation between the records based on changes in the low-field susceptibility and the inclination is extremely detailed. The time versus depth correlation has been established from the $\delta^{18}O$ record (0-140 kyrs B.P.).

The magnetic mineralogy is dominated by two components. The signal carried by magnetite is reflected by large variations in the low-field susceptibility and the intensities of the remnant magnetizations with strong increases during warm periods, while low values are observed during cold episodes. In contrast, the signal carried by the hard coercivity fraction is controlled by hematite and shows a significant increase during glacial episodes. These features are unchanged for cores located within and outside the upwelling of Somali. The records have been expressed in terms of terrigenous inputs after correction for the effects of dilution by carbonates. Fluxes of magnetite are interpreted as changes in the amount of river-transported sediments, while changes in fluxes of hematite are linked to dust transport by winds. These results will be discussed in connection with the changes in continental aridity in this area during the Late Pleistocene.

SETTLING-VELOCITY OF SAND-SIZE FRACTION FOR COMPARISON OF QUATERNARY GLACIAL/INTERGLACIAL SEDIMENTS FROM NORTHERN NORTH ATLANTIC

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Depositional environment varies significantly due to changes of the oceanographic circulation pattern during glacial/interglacial cycles in Quaternary times. Glacial times are generally characterized by high amounts of terrigenous detritus whereas interglacial maxima are mainly made up of biogenic particles with foraminiferal shells as main constituent.

Based on the determination of the settling velocity in a 'Settling Tube,' it is possible to define specific hydrodynamical properties. The settling velocity is influenced by size, density, shape, and surface roughness of the particles.

The result of a settling-tube analysis is a settling-velocity distribution with several peaks representing the modes of different particle-assemblages.

A next step is to characterize the sediment particles of the various peaks. This is done by means of a 'Separator,' where particles can be distinguished depending on their sinking rate (e.g., different species of foraminifers).

Finally, the peaks are expressed in percentage of the total settling-velocity distribution.

These results will be presented for samples from different core sites in the northern North Atlantic for oxygen isotope stages 1, 2, 5 and 6.

THE PERSIAN GULF: GIANT SEDIMENT WAVES AS INDICATORS OF LONG TERM CURRENT ACTIVITY?

J. Mienert (GEOMAR, Kiel, Germany), J. Thiede, and K. Maraschi

Environmental impact studies were performed (Nov./Dec. 1991) on the Mesopotamian shelf in the northern region of the Persian Gulf. The area has a small fresh-water inflow from the Tigris-Euphrates and Karun rivers at its head, which surrounded by sites of some of the earliest civilizations of human history and has developed into one of the richest oil regions of the globe. A cruise (RV AKADEMIK) to the 20 m to 60 m shallow Mesopotamian shelf resulted in a

geophysical survey covering an area of 4600 km^2 by side-scan sonar (EG&G, 105 kHz) and uni-boomer, acoustic-profiling records (EG&G, model 230-1). To ground truth the geophysical data the sea floor was sampled using box and gravity cores. Sediments vary from terrigenous muds to more biogenic carbonate sands which accumulate at a reef and towards the basin. Since the Persian Gulf was dry during the last glacial followed by a sea-level transgression during post-glacial times, it seems likely that the reef and the observed bedforms were developed during post-glacial times. The results of the detailed geophysical mapping program show large-scale SSW to NNE migrating asymmetric bedforms, that developed in a small area at the eastern flanks of the basin. Observed bedforms reach heights of up to 5 meters and wavelengths of up to 2 km in water depths of 50 m. The preferential orientation of the wave crests is NNE-SSW and stands in marked contrast to the surrounding sea floor. Presently, we cannot completely rule out the existence of a dune system beneath the bedforms which may have been developed during low stands of sea level. However, sediments from the upper three meters indicate a marine environment where the crests of the bedforms and the direction of migration may have been originally caused by tidal currents. The orientation of the crests line up with the river drainage system. Therefore, the migrating sediment-wave field may provide a long-term record of current flow history of the northern Persian Gulf, and possibly the drainage history of the Tigris-Euphrates river system.

POWER SPECTRUM ANALYSES OF STORM LAYERS IN HOLOCENE SEDIMENTS OF KIEL BAY: A TOOL FOR PALAEOCLIMATIC RECONSTRUCTION?

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The information on climatic conditions is essential for the interpretation of processes which affect the coastal zone. Climatic events cause sea level variations, currents and waves which are the main processes responsible for erosion and transportation of material. In Kiel Bay (western Baltic) bottom currents, generated by storms, transport major amounts of coarse grain sized particulate matter into the deeper parts of the glacial valley system where the sedimentation of mud dominates. This mud becomes interlayered with sand which is accumulated in significant horizons documenting specific events.

In order to estimate the feature of the storm layer sequence on cyclic, transient, or stochastic characteristics, the optical density of a x-radiograph from a sediment core sampled in Kiel Bay was digitized. In this x-radiograph the storm layers are marked by low densities. Bioturbation could destroy the layering and the sample has to be observed critically on these effects.

The determined sequence which was taken in 1989 comprises the most recent sediments form the past 50 years. By using dated horizons and converting the core depth into a time scale the fast Fourier transformation of the autocorrelation function gives an estimation of the power spectrum.

This estimation shows two significant peaks with period of 6-8 and 2 years. The result indicates that the process in formation of storm layers is rather cyclic than stochastic. In the upper layer of the sediment core the two year period dominates, whereas in the lower layer the 6-9 years cycle can be determined. The analyses of the power spectrum of storm-induced sediments might be a tool to reconstruct the climatic variations.

THE EAST GREENLAND CONTINENTAL MARGIN (65°N): ICE SHEET DECAY AND SEDIMENT FLUXES SINCE THE LAST DEGLACIATION

J. Mienert (GEOMAR, Kiel, Germany) and A. Wittmaack

The sedimentary processes on the East Greenland Continental Margin and the magnitude of sediment fluxes are strongly influenced by meltwater inflow and interactions between ice sheets, fjords and shelf environments. This, in turn, depends largely upon the oceanographic and corresponding meteorologic climates. Past meltwater flow changes may be indicated by an oxygen isotope record measured on the planktonic foraminifera (*N. pachyderma*, left-coiling) that corresponds to a record from the Arctic Ocean. This record is indicative of a low salinity layer possibly caused by meltwater. The records will be compared to sediment fluxes of the East Greenland Margin off Kangerdlugssuaq Fjord (65°N). Here, one of the most prominent cross-shelf troughs on the East Greenland continental margin may act as a major conduit for sediment transport and meltwater. Based on radio-carbon ^{14}C-ages, sediment fluxes appear to cluster in two environmental periods: ice sheet decays with extremely high rates of sedimentation within short periods of time (tens to hundreds of years) and modern sediment influxes with relatively low transport rates over a long period of time. The results reveal three main patterns: (1) A massive event of sediment discharge (up to AR bulk 290 g/cm^2/kyr) occurs at about 13,300 yrs. B.P. in the trough at the middle shelf (Core V) suggestive of substantial increases in meltwater and terrigenous supply rates. (2) At the inner shelf an increase in sediment discharge (up to AR bulk 90 g/cm^2/kyr) occurs at about 9,000 yrs. B.P. (3) Sediment fluxes on the exposed shelf and upper continental slope exhibit significantly lower rates (< 10 g/cm^2/kyr). Changes in sediment fluxes and sea-floor properties have been integrated into a descriptive box model showing the decay of the ice sheet during the last deglaciation.

ICEHOUSE SEA-LEVEL CHANGES, DEPOSITIONAL SEQUENCES, AND THE NEW JERSEY MARGIN

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The "New Jersey sea-level/mid-Atlantic Transect" (NJ/MAT) is an integrated program of ODP (Leg 150) offshore, supplementary nearshore, and onshore drilling designed to address the sequence stratigraphic record of the Oligocene-Recent interval. The primary goals of the NJ/MAT are: 1) to place constraints on the ages of major unconformities (sequence boundaries); 2) to compare the timing of these unconformities with ages predicted from the deep-sea $\delta^{18}O$ record; 3) to assess the amplitude of sea-level changes that may have caused these unconformable sequence boundaries; and 4) to evaluate the response of sequence architecture to glacio-eustatic forcing.

The $\delta^{18}O$ record provides a proxy for glacio-eustatic changes during the Oligocene-Recent "Icehouse World." We have interpreted 12 Oligocene-Miocene benthic foraminiferal $\delta^{18}O$ increases (= base of Zones Oi1-Oi2, Oi2a, Mi1, Mi1a, Mi1b, and Mi2-Mi7) as glacio-eustatic lowerings and hypothesized that they correlate with 12 sequence boundaries (= inferred eustatic lowerings) of Haq et al. (1987). If this is true, then the increases should be observable in low-latitude planktic $\delta^{18}O$ records as well. Previous studies lacked crucial low-latitude planktic $\delta^{18}O$ data across several of the benthic $\delta^{18}O$ increases. New low-latitude planktic foraminiferal $\delta^{18}O$ data show increases of at least 0.5 ‰ at approximately 21, 18, 16, 14, 13, and 11 Ma. We interpret these synchronous $\delta^{18}O$ increases in benthic and plankic foraminifers as large and rapid (>50 m in <1 M.y.) glacioeustatic lowerings. The increases represent m.y. scale changes in ice volume that may be observable as seismic sequences on the NJ margin. High-frequency "Milankovitch" scale variations may be superimposed on these longer term glacio-eustatic changes; although some 100 k.y. scale sequences may be recorded on the NJ margin, most of the high-frequency changes are below seismic resolution.

We used existing and new multichannel seismic (MCS) profiles, biostratigraphic data, and well log data to evaluate the sequence stratigraphic framework of the Oligocene-Recent on the coastal plain, continental shelf, and upper slope of New Jersey. We have identified as many as 15 candidate Upper Oligocene to Miocene depositional sequences beneath the continental shelf and upper slope. Five of the most prominent sequence boundaries recognized by previous workers may correlate with $\delta^{18}O$ increases and inferred eustatic lowerings of Haq et al. (1987), although their precise ages can only be determined by proposed drilling. The geometry and facies relationships of the sequences conform to the systems tract models with some regional differences. Proposed ODP drilling on the shelf and upper slope will provide facies constraints and ages of sufficient accuracy to evaluate the relationship between eustatic change and the deposition of siliciclastic sediments on a slowly subsiding passive margin.

BENTHIC FORAMINIFERAL $\delta^{18}O$ AND $\delta^{13}C$ FROM ODP LEG 138 SITE 849, 0-3 MA: IMPLICATIONS FOR PANAMA BASIN PALEO-PRODUCTIVITY AND GLOBAL OCEAN CIRCULATION

A .C. Mix (College of Oceanography, Oregon State Univ., Corvallis, USA), N.J. Shackleton, N. Pisias, J. Wilson, A . Morey, W. Rugh, T. Hagelberg, and the ODP Leg 138 Shipboard Scientific Party

A ~3-Ma benthic foraminiferal $\delta^{18}O$ and $\delta^{13}C$ record in ODP Site 849 (0° 11'N, 110° 31'W, 3851m), with mean sample spacing of 4 ky, gives a complete record of deep Pacific stable isotope variations over this time frame. Most analyses come from epifaunal *C. wuellerstorfi*. Site 849 $\delta^{18}O$ correlates well with Panama Basin Site 677 (Shackleton et al., 1990). $\delta^{13}C$ diverges significantly between sites, including those intervals of Site 677 containing mostly analyses of *C. wuellerstorfi*. The deep Panama Basin is a local carbon and nutrient trap due to decay of organic carbon in the basin. This makes its $\delta^{13}C$ lower than the deep Pacific. In a box model, water residence time in the basin (presently ~40 yr) and organic carbon influx (presently ~9 mg m^{-2} d^{-1} at 2400 m), control the $\delta^{13}C$ gradient between the Panama Basin and the open Pacific ($\Delta\delta^{13}C$). Residence time may respond to hydrothermal heat flux or tectonics affecting the sill depth. Carbon flux reflects export productivity.

The paleo-$\Delta\delta^{13}C$ gradients suggest that carbon flux has varied by more than a factor of two over the last 800 ka with an orbital rhythm of tilt (41 ky), with long-period variations (200-400 ka), and perhaps with precession (23 ky). Conspicuously absent from $\Delta\delta^{13}C$ over this interval is the 100-ka rhythm present in $\delta^{18}O$, suggesting independence of local productivity from high-latitude climate. In the 41 ka band, phase of $\Delta\delta^{13}C$ versus -$\delta^{18}O$ (+97 ± 31°) implies highest productivity during ice growth, or high northern-hemisphere winter

insolation. Over 3 Ma, the orbital character of the $\Delta\delta^{13}C$ record is less clear, although non-linear relationships to insolation or ice volume may be present. On this scale, stochastic variations in water flushing rate forced by hydrothermal heat input or tectonics affecting basin shape may also influence Panama Basin $\delta^{13}C$

A changing $\delta^{13}C$ gradient between the Panama Basin and the open Pacific means that Site 849 rather than Site 677 should be used as a reference section for mean deep Pacific $\delta^{13}C$ history at orbital and longer periods. Global circulation patterns over the past 3 Ma are reassessed on this basis.

AUTOMATED COLOR REFLECTANCE SPECTROSCOPY FOR RAPID CHARACTERIZATION OF DEEP-SEA SEDIMENTS: CALIBRATION WITH LITHOLOGIC DATA ON ODP LEG 138

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Digital color reflectance spectroscopy is a useful tool for rapid, non-intrusive characterization of major lithologies in deep-sea sediments. A new instrument developed at Oregon State University allows automated sequential measurement of reflectance in 511 wavelength channels across the visible and near-infrared bands (450-750 nanometers). This technique, tested on split cores during ODP Leg 138, provided rapid stratigraphic information which aided in the assembly of composite depth sections from multiple APC holes (see poster by Hagelberg et al.). At sea, preliminary data analysis revealed distinct color signatures related to carbonate and/or opal content (high reflectance) versus clay (low reflectance), and the presence of oxides (reflective in long wavelengths) versus sulfides (reflective in short wavelengths). Post-cruise studies have emphasized development of a uniform "ground truth" data set to calibrate color spectra. Our first priority is to separate the influence of opal and calcite. Initial results suggest that opal-rich and carbonate-rich sediments are associated with unique color signatures. Thus, color reflectance may prove useful for making non-intrusive estimates of calcite, opal, clay, and oxide content in a multi-component system. This technique will augment measurements of GRAPE density, which provide excellent estimates of carbonate content in two-component (carbonate-opal) systems, but are more difficult to use when three or more lithologic end members are present.

CRETACEOUS MARINE SCENARIO IN THE INDIAN SUBCONTINENT: A SYNTHESIS

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Geotectonic factors concommittant with the drifting of the Indian plate before the final continental collision with the Asian plate in the post-Cretaceous brought about significant changes in the marine pathways and depositional scenario in the Indian subcontinent. During the Cretaceous, pericratonic rift basins and shelves and few intracratonic rift basins developed, along with a clearer delineation of the Indian Ocean on the south and closure of the Neo-Tethyan Ocean on the north. Plate reorganization processes and two episodes (Lower and Upper Cretaceous) of flood basalt volcanism recorded from the

offshore part must have generated intraplate stresses leading to epeirogenic movements, causing regional sea-level fluctuations and, probably with an eustatic component, effected transgressive-regressive sedimentary cycles in different basins.

Marginal and intracratonic basins were partly fluvial and partly invaded by shallow marine seaways during Early and Mid-Cretaceous. A Late Albian-Cenomanian transgression event is recorded. Parts of basins remained under inner to outer shelf regime during Late Cretaceous. Sea level dropped towards Late Maastrichtian. Shallow Cretaceous seaways in the Tethys Himalayas showed gradual deepening of the shelf/ramp northwards in Late Cretaceous. Oceanic floor with ophiolites subducted northwards and was almost consumed during the Maastrichtian beneath an island arc and/or southern margin of a continent with magmatic arc, thus closing the Neo-Tethys. An arc-trench basin was developed flanking a flysch trough to the south. Flysch sediments are associated wih exotics and ophiolites. A Late Cretaceous seaway was probably present in the Lesser Himalayas. Neo-Tethys between Indian and Sino-Burmese continental blocks was also getting closed marked by ophiolites.

Palaaeobathymetry, in general, remained within outer-shelf regime. Chert with exclusively radiolarian assemblage in the Naga-Andaman ophiolites probably indicated oceanic depth below C.C.D. Dark grey/black shale associations in some basins suggest probably oceanic anoxic events between Albian-Cenomanian and during Mastrichtian.

PALAEOGENE TETHYAN SEAWAYS IN THE INDIAN SUBCONTINENT: A SYNTHESIS

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Tethyan seaways and a marine depositional scenario during the Palaeogene of the Early Cenozoic era in the Indian subcontinent were tectonically controlled mainly by plate motion; the resulting continental collision of the Indo-Himalayan continent with the Tibetan continent on the north between Late Palaeocene-Middle Eocene, and with the Central Burma microcontinent on the northeast during Late Oligocene when Neo-Tethyan oceanic crust was consumed on the collisional fronts.

The Tethyan seaway gradually closed and by Late Eocene the sea had totally regressed from the northern Himalayan belt. While shallow seaways were extending into the eastern and western marginal-coastal basins and the Assam-Meghalaya Shelf in the eoicene, in the oceanic realm of th naga Hills Ophiolite belt of th Indo-Burmese Range and in the Andamans, flysch-type sediments accumulated in deeper distal shelf/trench basins during the Eocene-Oligocene, with considerable shallowing taking place towards Late Loligocene...

Sea-level changes caused transgression and regression of varying temporal and spatial magnitude during the Palaeogene. Sedimentation patterns and events of a major change in the larger foraminiferal composition at the Eocene-Oligocene boundary may be linked to continental collisional tectonics, global sea-level fall and also probable climatic changes with cooling of surface oceanic waters.

Nowhere in India is reef-coral fauna found so abundantly as it is in the Kutch Basin in northwestern India. Kutch Oligocene reefal fauna is significant in paleoceanography as far as it afirms the connection of the northwestern Indian Ocean with the eastern Mediterranean during the Early Oligocene. Closing of the Himalayan Trethyan seaway on the north and the posible coeval widening of the southerly Indian Ocean due to collisional tectonics, generated a favorable

setting and Tethyan tyhpe paleoceanic circulation for the luxuriant development of reef coral fuana in northwestern India.

STATISTICS DEFINE ECOLOGIC CONTROLS OF FOSSIL PLANKTONIC FORAMS

B. Molfino (Lamont-Doherty Geological Observatory, Palisades, NY, USA)

This is a statistical approach to the long-standing question: what controls planktonic foraminifera biogeographies? I use a revised and expanded global data base of 1304 census counts. Physical and chemical parameters for the upper 300 meters of the ocean at each core-top site include (a) Levitus' seasonal temperatures and salinities, and annual oxygen, (b) Reid's phosphate (gridded and smoothed using GMT), and (c) the average mixed-layer depth. These parameters constitute possible ecologic controls of foram biogeographies. The question is how to select the probable ones. I present three studies.

(1) Rmode analyses of Atlantic parameters show upper waters defined by three eigenfunctions. Statistically independent depths are 0-75m (shallow), 100-150m (intermediate), and 175-300m (deep). Rmodes for collective parameters in various groupings support the 3-part separation. Depth configuration of parameters were simplified to seven variables: winter and summer surface temperature and surface salinity, 100m oxygen, 100m phosphate, and average mixed-layer depth.

(2) Pseudoboxplots graphically summarize environment-weighted histograms of species. Inter-ocean comparison of pseudoboxplots defines ecologic control by degree of statistical similarity. Pseudoboxplots of 27 species from Atlantic, Indian, and Pacific Oceans show temperature is the probable control of 20 species, but not a control of *G. crassaformis* and *C. nitida*. Salinity is a probable control for only 5 species (*N. dutertrei*, *G. inflata*, *G. truncatulinoides* left, *G. menardii*, and *G. tumida*). Oxygen, phosphate, and mixed-layer depth control some species.

(3) Constrained ordination (canonical correspondence analysis) graphically defines relationships between environmental parameters and species. The Tukey transform eliminates the correlation between seasonal parameters. Atlantic data indicate the primary control is mean temperature. Seasonality in salinity affects gyre-margin species (*N. dutertrei*, *G. tumida*), while seasonality in temperature affects transitional species (*G. hirsuta*, *G. falconensis*). Oxygen and average mixed-layer depth are inversely related to annual temperature. Phospate is more important for the high-latitude species (*G. quinqueloba*), though phosphate at greater depths is related to some gyre-margin species.

TECHNIQUE AND CALIBRATION BIAS IN PALEOESTIMATION

B. Molfino (Lamont-Doherty Geological Observatory, Palisades, NY, USA)

Technique bias asks whether significant differences exist among paleoestimates from different techniques and, if present, is there a definitive pattern? I test this spatially and temporally on foram paleotemperature techniques. I use Atlantic CLIMAP SST for calibration, and compare Imbrie-Kipp, Response Surface, and Modern Analog Techniques developed on two

faunal treatments: Five truncated assemblages and five species percentages (technique groupings). Statistical tests of sample and spectral variance constitute a qualitative meta analysis. Within-sample variances are computed by group; proportion of within-sample variances ≤ 1°C is the measure.

Spatial comparison uses 91 independent Atlantic core-tops. Assemblage-based paleoestimators show a random pattern of within-sample variance with a variance measure of ≥0.89 for both seasons. Five-species-based paleoestimators show coherent geographic patterns for both seasons, with a variance measure of ≤0.66 for T_{warm} and ≤0.37 for T_{cold}. Highest within-sample variances are found along the subtropical convergence.

Temporal comparison examines sample and spectral variances in a transect of three North Atlantic cores, from high to low latitudes. Assemblage-based paleoestimators consistently show high values for the variance measure for both seasons (≥0.80 for high and low latitudes; ≥0.65 for mid lat), while 5-species paleoestimators consistently show low values (≤0.46 for high latitude; ≤0.27 for mid and low latitudes) except for low latitude T_{warm} (=0.75). The Smirnov non-parametric statistic determines if the maximum difference between spectral cumulative distribution functions is significantly different. Assemblage-based paleoestimates do not differ while the 5-species paleoestimates differ only in the low-latitude core.

Technique bias is not dependent upon choice of statistical methodology, but on choice of faunal data treatment. Technique bias is not present among assemblage-based paleoestimators; it is present among 5-species paleoestimators.

Calibration bias does exist. I examine how CLIMAP and Levitus temperatures affect estimates by computing weighted means of 33 foram species, by ocean, using observed cold-season temperatures. Pairwise comparison shows species means are all ~0.5°C warmer under Levitus than under CLIMAP in the Atlantic and Indian Oceans, while equivalent in the Pacific.

OCEANOGRAPHY OF THE GULF OF TEHUANTEPEC, MEXICO, INDICATED BY RADIOLARIA REMAINS

A. Molina-Cruz (Inst. de Ciencias del Mar y Limnologia, UNAM. Ciudad Universitaria, México) and M. Martinez-Lopez

The morphology of the Gulf of Tehuantepec, Mexico, is redefined through a bathymetric analysis and this redefinition is considered to explain the distribution patterns of pelagic sediments; particularly that of radiolarians remains. Although the distribution patterns of pelagic sediments are influenced by the Gulf of Tehuantepec bathymetrical morphology, these "reflect" clearly, the regional oceanography. Northern and strong winds, called the "Tehuanos," blowing on the sea surface of this Gulf, when the Intertropical Convergence is at its southernmost position, define preponderant, the sedimentological dynamics of this region. This wind field originates an oceanic front at the southwestern part of the Gulf, as well as upwelling processes at its southeastern part. In the water mixing observed in the front, there is some contribution from the California Current; while in the upwelling processes, there is a large contribution of the tropical and subtropical water which is carried by the Costa Rica Coastal Current. This oceanographic framework defines the "make-up" of radiolarian assemblages. Consequently, at the sea-bottom, under the oceanic front, there is observed the presence of the radiolarian species *Cycladophora davisiana and Lithomelissa thoracites;* while under the upwelling region, the presence of *Polysolenia murrayana* is conspicuous.

LABORATORY EXPERIMENTS ON THE INFAUNAL ACTIVITY IN BENTHIC FORAMINIFERS

L. Moodley (Netherlands Institute for Sea Research, Texel, The Netherlands)

The infaunal activity of benthic foraminifers was examined in the laboratory in mini-aquariums using *Quinqueloculina seminulum* (Linné). Specimens buried in very fine sand at the bottom (37 mm) of the aquarium venture away, whereas specimens buried with a subsurface oxic layer, created by an air-flushed, artificial macrofaunal tube, remained at the bottom of the aquarium.

Specimens placed on the sediment surface, with or without an air flushed tube placed diagonally through the sediment column, did not migrate deeper than 15 mm into the sediment.

These results suggest that the occurrence and activity of benthic foraminifers deep below the surface oxic zone of the sediment is associated with macrofaunal activity. The method used in this study is simple and can be used to compare the behavior of different species under different subsurface oxygen gradients, as well as food gradients.

SEISMIC STRATIGRAPHY OF THE ONTONG JAVA PLATEAU: PALEOCEANOGRAPHIC SIGNIFICANCE

D.C. Mosher (Dept. of Oceanography, Dalhousie Univ., Halifax, Nova Scotia, Canada) and L.A. Mayer

Study of the sedimentary column down the flank of the Ontong Java Plateau, in water depths ranging from 2000 m to 4500 m, provides a means of examining spatial and temporal responses of carbonate sedimentation to paleoceanographic changes. These responses are often reflected in physical properties of the sediment which, in turn, control the appearance of seismic reflection profiles.

Seismic reflectors of the 1300 m thick sedimentary section at the top of the plateau are largely flat-lying and suggest pelagic sediment deposition. Profiles down the flank of the plateau undergo three significant changes: (l) Drastic thinning of the sediment column (65% between 2000 and 4000 mbsl), attributed to increased carbonate dissolution with depth. (2) Development of large impedance contrasts resulting from condensed sediment sections and hiatuses. (3) Loss of continuous, coherent reflections downslope resulting from sediment mass movement and faulting.

Laboratory and well-log density and velocity data from five ODP sites on the flank were used to model the seismic response of the sediment column. Changes in velocity and density (the causes of seismic reflections) are largely related to grain-size changes (abundance of foraminifers) which, in turn, are a function of carbonate preservation /dissolution changes and sedimentation processes. Correlation of seismic reflection data with synthetic seismograms and, hence, with depth below seafloor at each drill site, shows that a single velocity-depth function exists for sediments on the top and flank of the Ontong Java Plateau. Sediment thickness data suggest a shallow lysocline in the Early Miocene, followed by a deepening in the Late-Early Miocene. A sharp rise in the lysocline and a steepening of the dissolution gradient is suggested for the

Middle Miocene. A further depeening in the Late Miocene followed by a rise in the very Late Miocene and Pliocene is interpreted.

THE EFFECT OF CHANGING CONTINENTAL WEATHERING RATES ON ATMOSPHERIC CO_2 OVER GLACIAL TO INTERGLACIAL TIME SCALE

G. Munhoven (Institut d'Astrophysique, Université de Liège, Belgium) and L.M. François

A nine-box model of the ocean-atmosphere subsystem of the global carbon cycle has been developed to study the effects of some possible scenarios of the last glacial-interglacial transition. It has been adjusted to reproduce the distributions of total dissolved inorganic carbon, total alkalinity, phosphate, $\delta^{13}C$ and the $\Delta^{14}C$ of the modern ocean and the partial pressure of atmospheric CO_2. A simple sedimentation scheme at 20 different depth levels drives carbonate deposition and dissolution as a function of the depth of the (dynamic) calcite lysocline in each of the three ocean basins considered (Atlantic, Antarctic and Indo-Pacific). Furthermore, we have added a simple strontium cycle to take advantage of the recently published $^{87}Sr/^{86}Sr$ data for the last 300,000 years (Dia et al., *Nature*, **356**, 786-788, l992). These data are used to construct different scenarios of changes of the continental weathering rates of silicate and carbonate rocks. They indicate that the related carbon and alkalinity fluxes entering the ocean-atmosphere system may have been substantially higher during glacial times than today. These variations may explain part of the observed changes of the partial pressure of atmospheric CO_2 between glacial and interglacial periods.

CRETACEOUS FERROMANGANESE AND PHOSPHATIC HARDGROUNDS ON THE WESTERN PACIFIC GUYOTS

I.O. Murdmaa (P.P. Shirshov Institute of Oceanology, Academy of Sciences, Moscow, Russia)

Ferromanganese crusts and phosphorites occur as hardgrounds on the great majority of western Pacific Guyots. Such hardgrounds were drilled during ODP Leg 143 on Allison and Huevo guyots of the Mid-Pacific group with the Lower Cretaceous volcanic edifices. The major hardgrounds occur at the top of the Albian shallow-water carbonates, matching hiatus surface separating the latter from the Paleogene to Upper Cretaceous pelagic carbonates. Condensed basal pelagic carbonates are also affected by manganese impregnation and phosphatization. Moreover, discrete phosphate layers were traced within the Albian shallow-water section down to 62 m. The hardgrounds are associated with long-term, non-depositional environments, particularly with those existing during guyot drowning in the Late Cretaceous

Ferromanganese oxides precipitated from bottom waters at the water-hard rock interface. the metasomatic phosphatization can be explained by precipitation from upward filtrating interstitial waters at the interface, which serves as a geochemical barrier. Phosphorus in such models is supplied from underlying organic-rich sediments or basalts.

BIOGENIC FLUXES AT ODP SITE 847, EASTERN TROPICAL PACIFIC DURING THE PAST THREE MILLION YEARS

D.W. Murray (Dept. of Geological Sciences, Brown Univ., Providence, RI, USA) and J.W. Farrell

ODP Site 847 (0.12°N, 95.19°W, 3335 m), drilled beneath the high productivity region of the eastern tropical Pacific, provides continuous high resolution records (~ 5 ky sampling interval) of calcium carbonate, opal, and non-biogenic sedimentation during the past 3 M.y. (0-102 mbsf). The sediments are dominated by calcium carbonate having a mean concentration of more than 60%. Opaline silica and terrigenous material each range from about 6 to 50% over the interval studied. Fluctuations in sediment composition are largely attributed changes in carbonate dissolution and opal flux. Terrigenous input is less variable.

Oxygen isotope chronostratigraphy is used to calculate high-resolution changes in sedimentation rate during the past 1 M.y. The mean accumulation of calcium carbonate varied between 4 and 20 g/m^2/yr during the past 1 M.y. An interval of low mean carbonate (<5 g/m^2/yr) and high mean opal accumulation (>4 g/m^2/yr) is found between 220 and 70 ka. This same pattern of sedimentation is observed in sediments from nearby piston cores and DSDP Site 572.

Biostratigraphic data are used to quantify sedimentation rates between 1 and 3 M.a. Over this time, interval mean carbonate accumulation ranges between 2 and 15 g/m^2/yr. Mean opal and terrigenous accumulation each vary between 2 and 5 g/m^2/yr. In addition to the 0.07 to 0.22 M.a. section, intervals enriched in opal with concentrations of more than 30% are observed within 1.7 to 2.0 and 0.9 to 1.4 M.a. These records from ODP Site 847 will be compared to time series of mean biogenic sedimentation from DSDP sites cored in the eastern and central equatorial Pacific.

THE ARCTIC OCEAN RECORD: KEY TO GLOBAL CHANGE

NAD Nansen Arctic Drilling Program (c/o L. Johnson, Chairman, NAD Executive Committee, ONR, Arlington, VA, USA) and Members of the NAD Committees

The primary goals of the Nansen Arctic Drilling Program are to understand: 1) the climatic and paleoceanographic evolution of the Arctic region and its effects on global climate, biosphere, and dynamics of the world's ocean and atmosphere; and 2) the nature and evolution of the major structural features of the Arctic Ocean and circum-Arctic continental margins. The profound influence of the Arctic Ocean on the global environment, the rapid fluctuations of the Arctic ice cover and its consequences for global change, and the unresolved tectonic problems of the northern hemisphere have resulted in a growing pressure towards attempting to drill the deep-sea floors of the ice-covered Arctic Ocean. The sediments beneath the Arctic Ocean are recorders of long- and short term northern hemisphere cooling and its linkages to bottom water renewal and biotic adaptation. The underlying basement rocks will reflect the origin and tectonics of the basin and its contained ridges and plateaus, which are unsampled and of unknown origin. In a first step NAD will attempt to drill relatively shallow sites in the marginal regions of the Arctic, such as the continental slopes off the McKenzie and Lena deltas, as well as the Yermak and Chuckchi plateaus, while a concerted multidisciplinary effort to explore the central Arctic will be attempted once the most promising drilling technique has been defined.

NAD is complimentary to the efforts of ODP which will visit the Norwegian-Greenland Sea during Leg 151 in the late summer of 1993 and possibly for an additional leg during one of the ensuing years. Primary goals of drilling arctic and sub-arctic locations as part of ODP are addressing the history and mode of water exchange between the Arctic Ocean proper and the Norwegian-Greenland Sea through Fram Strait and between the Arctic deep-sea basins and the main North Atlantic Ocean across the Greenland-Scotland Ridge.

Ref: Nansen Arctic Drilling Program NAD Science Committee 1992: The Arctic Ocean Record: Key to Global Change.-Polarforschung 61 (1): 1-102. Ruddiman, W. and NAAG-DPG, 1991: North Atlantic Gateways.- JOIDES J., 17 (2): 38-50.

CHANGES IN SEDIMENTARY FACIES ALONG THE EAST GREENLAND CONTINENTAL MARGIN: IMPLICATIONS FOR THE GLACIAL/INTER-GLACIAL HISTORY OF GREENLAND DURING LATE QUATERNARY TIMES

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Detailed sedimentological and organic-geochemical investigations of marine sediments from the East Greenland Continental Margin between 69°N and 75°N have been performed in order to get informations about the glacial/interglacial variations of paleoenvironments and to link the terrestrial and deep sea paleoclimatic records. The reconstruction of the environmental history of the East Greenland Margin and the correlation between terrestrial and marine records are major objectives of the ESF-PONAM-Programme (European Science Foundation - Polar North Atlantic Margins).

Marine sedimentation processes, terrigenous sediment inputs, and biogenic productivity in the study area are mainly influenced by fluctuations in extent of the Greenland Ice Sheet, extent of sea ice, rate of drifting icebergs, melt-water input, changes in the East Greenland Current and/or oceanic circulation, i.e., all factors are controlled by climate. Based on oxygen stable isotope stratigraphy, distinct changes in relative abundances of biogenic and siliciclastic sediment components and grain-size distribution recorded in the sediments from the East Greenland Continental Margin indicate major variations in the depositional history in these environments through late Quaternary glacial/interglacial cycles.

The drastic climatic change from last glacial maximum to present deglacial conditions is clearly documented in the marine sedimentary sequences from shelf and upper slope environments. A facies succession on the shelf from overconsolidated diamicton/lodgement till to alternation of diamictons and varved clay to bioturbated glacial-marine sediments reflect the gradual retreat of continental ice masses/glaciers during glacial/interglacial transition (termination). This process resulted in distinctly decreased supply and deposition of ice-rafted debris in the open shelf/upper slope environments. During Termination I, the sea-ice cover also decreased, causing an increase in surface-water productivity as indicated in increased organic carbon and biogenic opal deposition.

VARIATION OF LATE MAASTRICHTIAN PLANKTIC FORAMINIFERAL FAUNAS WITH 20 KA PRECESSION CYCLES

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To determine the existence of short term variation in Late Maastrichtian planktic foraminiferal faunas across marly limestone - marl alterations, we analyzed some 90 samples from three intervals, each spanning two carbonate rich and two clay rich levels in the *A. mayaroensis* Zone. Samples were collected from land sections near Bidart (France) and El Kef (Tunisia), and from DSDP Site 605 (NW Atlantic). The variation in carbonate content is interpreted as a primary signal related to the approx. 20 ka precession cycle.

At all three localities, changes in carbonate content are accompanied by changes in faunal composition, without affecting preservation. In general, carbonate rich levels have a higher number of foraminifera per gram sediment, lower diversity and more abundant globular species. Globotruncanids and strongly ornamented heterohelicids are more frequent in the clay-rich samples. In combination with the stable isotope signal this suggests that variation in carbonate content is at least partly the result of changes in paleoproductivity levels and not that of dilution by clay only. Low diversity faunas in carbonate rich levels at DSDP Site 605 and in the Kef section are interpreted as opportunistic, while the higher diversity faunas from the clay rich levels represent more stable conditions. In the Bidart section, higher diversity in the clay rich levels corresponds to an enrichment in both specialistic and opportunistic species, suggesting stronger seasonal variation.

THE BENTHIC FORAMINIFERAL RESPONSE TO GLACIAL/INTERGLACIAL TRANSITIONS IN A HIGH-RESOLUTION CORE SEEN AS A POSSIBLE CHANGE IN PALAEOPRODUCTIVITY

S. Nees (Special Research Project 313, Christian-Albrechts Univ., Kiel, Germany)

The glacial/interglacial transitions (terminations) reflect the most profound climatic changes of the Late Pleistocene. To analyze the palaeoenvironmental changes in the deep-sea for such periods three long sediment cores along a north-south transect in the Norwegian-Greenland Sea were examined in detail. Samples were taken in intervals of 3 cm and for each the benthic foraminiferal content of the sediment was counted.

In comparison with the oxygen isotope data, the benthic foraminiferal community shows a more distinct and different response to climatic and subsequently oceanographic changes. An extremely low abundance (e.g., < 10 tests per gram dry sediment = t/g) is followed by a maximum peak (e.g., < 1130 t/g) and general high abundances (300 - 600 t/g) occur after interglacial conditions.are well established. This maximum peak marks a major environmental modification of the deep sea. Whereas agglutinated foraminifers and infaunal species in glacials predominate (max 71%), epifaunal species like *Pyrgo murrhina* (max. 56%) and especially clinging species like *Cibicidoides wuellerstorfi* (max. 68%) display apparent "blooming" conditions. In the Central Norwegian Sea at the termination I (oxygen isotope stage boundary 2/1, 15 - 8 ky bp) the benthic foraminifers show a stepwise increase in abundance going up to a maximum of 950 tests per gram dry sediment. At termination II (oxygen

isotope stage boundary 6/5, 135.1 - 125 ky bp) the benthic foraminiferal content increases in all cores and reaches a maximum peak of up to 638 t/g very rapidly.

The benthic foraminiferal community clearly displays a major impact of the deglaciation processes on the deep-sea environment. At glacials static habitat conditions on the sea floor generate a stable balance between low nutrient flux, and thus species, which are also adapted to the high sediment input. As soon as the ice cover retreats, productivity in the upper layers of the ocean near the sea surface commences (= "ice edge blooming effect") and a surplus of nutrient thus starts to travel through the water column. New initiated ocean currents than transport the nutrient down to the sea floor, where clinging benthic foraminifers and other epibenthic species thrive.

HIGH RESOLUTION RECORD OF CHANGES IN MONSOONAL PATTERN OVER INDIA OVER THE LAST 4,500 YEARS: FORAMINIFERAL EVIDENCES

R. Nigam (National Institute of Oceanography, Goa, India) and N. Khare

To face offing changes in monsoonal pattern, a consequence of global warming due to the Greenhouse effect, predictive models are required. Highly resolved records of paleomonsoons are the prerequisite for predictive models. These records are available in marine sediments.

Based on 50 surface sediment samples from the western continental shelf of India, it is established that *Cavarotalia annectens* (Parker and Jones) is adversely affected by fresh water through river discharges. Thus, fluctuations in the abundance of this species in cores at the margins of river mouth microenvironments are expected to be in phase with pulsation of this microenvironment, which depends on the amount of fresh water runoff, a measure of the monsoonal rainfall over the river's catchment area.

Following this approach, the paleomonsoonal history is constructed for a period of the last 4,500 years (A.M.S. dates) through the study of a core (14° 49.43'N, 73° 59.77'E, at 22m water depth), where maximum time resolution is 50 years. The results show less precipitation at ca. 1070, 2745 and 4245 years BP, punctuated by high precipitation. These fluctuations are close to the periods of "all planetary conjunction" having a cycle of ca. 1668 years.

Another core (14° 53.1'N, 73° 57.9'E, water depth 20m), provided approximately 450 years record (210Pb dates), with a time resolution of ca. 20 years. Based on abundance of *C. annectens,* we inferred significant variations in monsoonal precipitations and cyclicity of approximately 77 years in dry periods. Meteorological rainfall record of India for the past 100 years also show traces of this cycle. A prominent association has been observed between this cycle and Gleissberg cycle of sun. Similar cycles are also witnessed by many paleoclimatic records from many parts of the world.

LARGE-SCALE CHANGES IN THE CALCAREOUS NANNOPHYTOPLANKTON WHICH BUILT PURE MESOZOIC LIMESTONES

D. Noël (URA 12, Géologie Muséum, Paris, France) and G. Busson

The study is based on : 1 - Liassic to Barremian, fine-grained, clay-poor limestones from numerous sections in Italy, France, Tunisia, etc ; 2 - upper Cretaceous chalk from Paris basin ; 3 - deep-sea sediments (DSDP-ODP) .

Facies and nannofacies analysis focused on the micropaleontological content of these limestones led us to individualize four large and contrasted periods of time .

In the first three the bulk of the limestones is mainly made of the remains of only one group of phytoplankton ; other biota being subordinate.

1- The Liassic times (including Aaalenian) = 25 M.Y : the reign of schizospheres: Limestones made of valves of schizospheres and their diagenetic products were generated at a world-wide scale, both in shallow environment and in deep depocenters.

2- The Middle-Upper Jurassic times (Bajocian to Tithonian) = 30-35 MY : the dominance of minute-sized, "cuff-link" shaped coccoliths: Limestones made of oligospecific assemblages of coccoliths (minute-sized, cuff-link shaped) were generated in various environments : deep-sea, epicontinental basins, platforms and even back-reef and lagoonal environments.

3- The Latest Tithonian and Early Cretaceous (Berriasian to Barremian) times = 20 MY : the reign of nannoconids: In epicontinental environment, nannoconids played a paramount role in the genesis of fine-grained , clay-poor limestones at a world-wide scale.

4- The Upper Cretaceous times (Cenomanian to Maastrichtian) = 20 MY : coccolithophorids as rock-builders of the chalk: Then the seas were inhabited by a lot of coccolithophorids with normal and rather large sizes belonging to numerous species. Their remains made the bulk of the chalk . Other biota were well developed alike .

It can be assumed that some oceanographic, global factors induced the characteristics of nannoplankton which lived in the different periods of time and its changes .

HOW DID THE RECENTLY PRESENTED DRAINAGE OF THE BALTIC ICE LAKE, FROM 12,700 BP, AFFECT THE CLIMATIC DEVELOPMENT IN THE CIRCUM-ATLANTIC REGION?

K. Nordberg (Dept. of Oceanography, Univ. of Göteborg, Sweden), and
H. Bergsten

From stratigraphic investigations of Late Weichselian records in the southern Kattegat, Scandinavia (Bergsten and Nordberg, 1992) a major unanswered question, discussed among North European Quaternary geologists for about one hundred years, can be answered. The question was if and where the Baltic Ice Lake had an outlet before c. 10,300 years BP, when the well-known dramatic drainage through south central Sweden took place.

From sediment records from the southern Kattegat covering the last 13,500 yrs BP we conclude: (**a**) that there was a sudden opening of a passage in the Öresund Strait at c. 12,700 BP, through which huge amounts of melt-water were drained until 10,300 BP. The opening of the Öresund Strait is identifiable from a distinct alteration in lithological and biostratigraphical variables of the sediments in the Kattegat. (**b**) That a colder phase occurred between 11,500 and 10,600 BP. This is suggested by decreased accumulation rates and increased abundances of salt demanding foraminiferal species. Faunal characteristics suggest that bottom-water temperatures remained fairly unaffected. (**c**) That there is faunal evidence for a climatic warming close to 10,500-10,600 BP. (**d**) That a sudden change in the drainage pathway of the Baltic Ice Lake from the Öresund Strait to south central Sweden, took place about 10,300 BP. Until then, accumulation of 'Baltic' sediments took place in the southern Kattegat, when the records are interrupted by a hiatus. (**e**) That the drainage of fresh Baltic water

through the Öresund Strait, during the Late Weichselian, was a major driving force for an inflow of marine water from the Skagerrak-North Atlantic Ocean into the southern Kattegat, as is occurring at the present time.

Attention all paleoceanographers!

- How does this, until now unknown, significant influx of melt-water from the Baltic Ice Lake, from 12,700 BP, affect the models which take into account the melt-water influx to the North Atlantic Ocean during Late Glacial time?
- How is this drainage episode mirrored in the stratigraphic records of the North Sea and the North Atlantic Ocean?

Bergsten, H. & Nordberg, K., 1992: Late Weichselian marine stratigraphy of the southern Kattegat, Scandinavia: evidence for drainage of the Baltic Ice Lake between 12,700 and 10,300 years BP. *Boreas 21*, p. 000-000.

A HIGH-RESOLUTION, 400,000 YEAR SEDIMENTARY RECORD OF THE LOMONOSOV RIDGE (CENTRAL ARCTIC OCEAN)

N.R. Nowaczyk (Univ. of Bremen, Germany), A. Eisenhauer, T. Frederichs, G. Gard, H. Hubberten, H. Kassens, A. Mangini, N. Nørgaard-Pedersen, R.F. Spielhagen, R. Stein, and the ARCTIC '91 Shipboard Scientific Party

During the international multidisciplinary ARCTIC '91 expedition, several sediment cores up to 17 m in length from the eastern and central Arctic Ocean were taken from RV POLARSTERN. In this study core PS 2185 (7.70 m) from the top of the Lomonosov Ridge (87.5°N, 144.9°E, 1052 m water depth) was selected to investigate the Late Quaternary depositional environment of the ice-covered central Arctic Ocean. The sediments are characterized by cyclic changes in color and sediment composition and by variations of physical properties, e.g., magnetic susceptibility, which reflect distinct paleoenvironmental changes. Bioturbated layers are intercalated with homogenous sequences and layers of small mud clasts.

For the first time, it was possible to combine magnetostratigraphic and ^{230}Th data, the oxygen isotope record of planktic foraminifers, and the coccolith abundance pattern to establish a high-resolution 400,000 years stratigraphy for the Lomonosov Ridge. All stratigraphic parameters indicate high sediment accumulation rates of 1-3 $g/cm^2 \cdot ka$ for this region, which are an order of magnitude higher than previously published for the Amerasian Basin.

High amounts of ice-rafted detritus (25-30%) were observed in oxygen isotope stages 2-4 and 6, whereas sediments older than stage 6 contain less than 10%. In general, carbonate contents are very low (< 1%) with two exceptions during oxygen isotope stages 5 and 1, where maximum values of 4% and 10%, respectively, were reached. Organic carbon contents vary between 0.1 and 0.5% during oxygen isotope stages 1 to 5, whereas in sediments older than stage 5, constantly low organic carbon contents of 0.2% occur.

Occurrences of coccoliths in various layers (including stage 5 and the Holocene) suggest seasonally open waters in the central Arctic Ocean during short intervals of the Late Quaternary.

MAGNETOSTRATIGRAPHY OF LATE QUATERNARY ARCTIC OCEAN SEDIMENTS: THE AMUNDSEN BASIN

N.R. Nowaczyk (Universität Bremen, Germany), T. Frederichs, and the ARCTIC '91 Shipboard Scientific Party

During the international expedition ARCTIC '91 with RV POLARSTERN into the central Arctic Ocean, a large number of long sediment cores were recovered. Seven cores from a transect between 60° and 110°E at 87.5°N in the Amundsen Basin and one at the North Pole were analyzed for rock magnetic and paleomagnetic properties.

High-resolution susceptibility measurements were obtained both by continuous whole-core logging and a new spot reading sensor. Most of the results reflect a rather complex sedimentation pattern, in particular, in the lower parts of the cores. Here, numerous turbiditic sand layers yield susceptibility values an order of magnitude higher than those of the silty clays in the upper section of the sediment column. Distinct features in the downcore susceptibility variations can be used for a detailed site-to-site correlation. The sediment colors were also considered as a lithological indicator to support this correlation.

The cores were sampled at 4 to 5 cm intervals for magnetostratigraphic analysis. The stable direction of the remnant magnetization of each sample was determined using a cryogenic magnetometer and progressive AF demagnetization. Normal polarity prevails in all investigated cores. A number of short intervals of negative inclinations are representing geomagnetic polarity events within the Brunhes Epoch. The magnetostratigraphic data result in late Quaternary sedimentation rates of the order of 1 cm/kyr or more in the Amundsen Basin.

MAGNETO AND OXYGEN ISOTOPE STRATIGRAPHY OF LATE QUATERNARY SEDIMENTS FROM THE CEARA RISE: EVIDENCE FOR POLARITY EVENTS WITHIN THE BRUNHES EPOCH

N.R. Nowaczyk (Univ. of Bremen, Germany), W. Thießen, and S. Mulitza

During RV METEOR cruise M16/2 nine gravity cores were taken along two transects across the northeastern flank of the Ceará Rise. A high-resolution magnetostratigraphic investigation on basis of vector analyses of the remanence components separated by progressive AF demagnetization was done to define the paleomagnetic signature of all sediments recovered. The characteristic remanent magnetization logs obtained reveal a series of polarity reversals of the geomagnetic paleofield. Age control is provided by oxygen isotope records for two of the cores. The oldest sediments sampled reach oxygen isotope stage 11. All intervals of reversed magnetization can therefore be related to polarity events within the normal Brunhes Epoch: Mono Lake (15-25 ka), Laschamp (40-60 ka), Norwegian-Greenland Sea and Blake I (80-120 ka), Blake II (130-140 ka), Biwa I (200 ka), Biwa II (280-300 ka) and Biwa III (360-370 ka). Ages in brackets are based on the present oxygen isotope stratigraphy time frame. Continuous whole-core measurements of magnetic susceptibility are used for a detailed correlation of the cores and show a perfect link to climatic cycles, high susceptibilities being typical for cooler, low susceptibilities for warmer periods.

This is the first time that the Brunhes Epoch polarity events could be confirmed in a series of cores taken at equatorial latitudes. Compared to their recordings in more than 25 cores from northern high latitudes, there appear to exist some differences in the timing of onsets and terminations. Nevertheless, there is now strong evidence that these geomagnetic events are global features.

THERMAL EVOLUTION OF NORTH ATLANTIC SURFACE WATER MASSES OVER THE LAST 200 KA- GEOCHEMICAL AND MICROPALEONTOLOGICAL INDICATIONS

D. Nürnberg (Alfred Wegener Institute, Bremerhaven, Germany), and K.-H. Baumann

The geochemical and paleontological investigations of deep sea sediment cores located along a N-S-trending profile in the northernmost North Atlantic and the Norwegian-Greenland Sea indicate new aspects in the paleoceanographic development of the Norwegian Current.

Geochemical analyses on fossil tests of the planktonic foraminifer *Neogloboquadrina pachyderma* sin. reveal that magnesium in foraminiferal tests reflects relative surface water temperature changes. Since the incorporation is uninfluenced by salinity changes of surface waters, magnesium provides an exclusively "thermal" signal. Studies on coccoliths in the Norwegian-Greenland Sea reveal that abundances strongly vary in accordance to climatic changes. Coccoliths are mainly restricted to interglacial core sections, indicating variable oceanographic regimes through time.

The combination of quantitative coccolith data and magnesium in foraminiferal tests makes a differential paleoceanographic reconstruction of the Norwegian Current possible. Significant magnesium variations in *N. pachyderma* sin. during isotopic stages 6 and 3 characterize a more variable surface-water circulation than previously assumed. At the beginning of stage 5, the drastic increase of magnesium concentrations accompanied by a successive appearance of various coccolith species indicates the starting influx of relatively warm North Atlantic surface water masses. In accordance to coccolith data, magnesium data indicate an establishment of the Norwegian current even during substages 5.3 and 5.1, whereas during substages 5.4 and 5.2, a drastic cooling of surface waters and/or a complete reduction of inflowing North Atlantic surface waters occurred. For the glacial stages 4 and 2, the interruption of inflowing surface waters has to be considered due to very low magnesium concentrations. The climatic change to the Holocene is reflected both in a drastic increase in magnesium concentrations and high coccolith abundances indicating a severe influx of relatively warm North Atlantic surface water masses. During Termination I_A, these surface waters presumably reached Vøring Plateau, but established in Fram Strait not before Termination I_B.

SEDIMENTS IN THE ARCTIC SEA ICE

D. Nürnberg (Alfred Wegener Institute, Bremerhaven, Germany), D. Dethleff, H. Kassens, T. Letzig, E. Reimnitz, and J. Thiede

Due to its exposed position and the unequal relationship between area and mean thickness, the sea-ice cover is expected to react sensitively on even small environmental changes. The importance of sedimentary inclusions in the Arctic ice cover on ablation processes, and on albedo effects related to such changes, is still not sufficiently known. Intensive studies on sediment inclusions in the

Arctic sea-ice cover have been concentrated on the central Arctic Ocean (Arctic '91), on main ablation areas in the Greenland Sea and Fram Strait, and, most recently, on source areas in the Laptev Sea area. Primary research objectives include the quantitative sediment analyses, the documentation of the regional distribution pattern of material-laden ice, the evaluation of processes by which sediment is incorporated into the ice cover, and the identification of transport paths and probable depositional centers for the sediment.

Sea-ice sediments are dominated by fine grain sizes, though coarse sediments and stones up to 5 cm in diameter could be observed. The component analysis reveals quartz and clay minerals to be the dominant terrigenous sediment particles. Therefore, clay mineralogy of ice-rafted sediments provides important indications for ice-drift patterns. The biogenous components point to a shallow marine source area for the sea ice sediments, indicating that terrigenous sediments have already been deposited on shelf areas before being incorporated into the sea ice by suspension freezing.

Observations in the Laptev Sea area (Siberian Arctic) indicate that frazil and anchor ice generating in a large coastal polynya provide the main mechanism to bring sediment into the sea ice. The sediment in Laptev Sea ice is distributed diffusely over the entire ice column (turbid ice), whereas in the Central Arctic Ocean sediments are already concentrated in layers or on ice floe surfaces due to various melting and freezing processes. Consequently, the sediment load in central Arctic multi-year sea ice exceeds by far the amounts observed in one-year sea ice from the Laptev Sea.

AN 180,000 YEAR MAGNESIUM RECORD IN *NEOGLOBOQUADRINA PACHYDERMA* SINISTRAL - A TOOL FOR THE THERMAL RECONSTRUCTION OF NORWEGIAN SEA-SURFACE WATERS

D. Nürnberg (Alfred Wegener Institute, Bremerhaven, Germany)

The variations of magnesium in calcitic tests of planktonic foraminifers (*Neogloboquadrina pachyderma* sin.) enables the spatial and temporal reconstruction of the thermal structure of ocean surface water masses even at high northern latitudes. Sediment cores from the Norwegian Sea and Fram Strait were used to systematically investigate these geochemical variations for glacial/interglacial changes during the past approximately 180,000 years.

The quantitative measurement of magnesium was performed by electronmicroprobe analyses in foraminiferal tests. Sample contamination, as well as the influence of early diagenetical processes potentially altering the original element content, can be ruled out at least for the time period considered here.

For the first time, the temperature-related calcium substitution by magnesium is shown in tests of *N. pachyderma* sin. Generally, relatively high magnesium concentrations appear during interglacials, whereas low magnesium concentrations occur during glacial periods. Even short climatic events such as the Younger Dryas cooling are reflected in the magnesium signal. Comparison to oxygen isotope data suggest that the magnesium signal is not influenced by salinity changes, thus providing an alternative tool to reconstruct relative surface water temperature variations.

During oxygen isotope stages 6 and 3 significant magnesium variations reflect a spatially and temporally differentiated surface water circulation. The drastic increase in the magnesium concentration at the beginning of stage 5 points to the onsetting influence of relatively warm North Atlantic surface waters into the Norwegian-Greenland Sea. A significant cooling of surface water masses can be observed from magnesium data for the remaining stage 5, as well as for glacial stages 4 and 2. The climatic "improvement" at the beginning Holocene was launched by the influx of relatively warm North Atlantic water masses, which reached Vøring Plateau during Termination I_A, but Fram Strait not before Termination I_B.

OXYGEN AND CARBON ISOTOPES OF INDIVIDUAL FORAMINIFERAL SPECIMENS COLLECTED FROM SEDIMENT TRAPS IN THE JAPAN TRENCH

T. Oba (College of Liberal Arts, Kanazawa Univ., Japan), K. Uomoto, and S. Honjo

Oxygen and carbon isotopic measurements of individual foraminiferal specimens provide useful information on understanding the depth habitat of each planktonic foraminiferal species. About 800 isotopic measurements were performed on individual specimens of eleven planktonic foraminiferal species collected from sediment traps deployed at 4,000 m and 9,000 m water depths in the Japan Trench. The results indicate that the oxygen and carbon isotopes of nine of the species, except for *Globigerinoides ruber* and *Orbulina universa*, were mainly controlled by the temperature and the carbon isotopic composition of the sea water in which the specimens lived. The oxygen and carbon isotopes of surface dwelling species are significantly affected by the seasonal changes of the temperature and carbon isotopes of the sea water, showing large isotopic variation more than 3‰ for oxygen and 2‰ for carbon in the case of *Globigerinoides sacculifer*. The effects of the seasonal changes are relatively small for the subsurface dwelling species such as *Globorotalia inflata* and *Globorotalia truncatulinoides*, which represent positive correlation between oxygen and carbon isotopes of their tests. All the species examined in this study have different oxygen and carbon isotopic values in relation to the test size. The depth habitat of main species inferred from the oxygen isotopic results are as follows;

Species	Depth habitat
Globigerinoides sacculifer	0 ~ 270 m
Globigerinoides conglobatus	50 ~ 200 m
Globigerinella siphonifera	50 ~ 400 m
Neogloboquadrina dutertrei	50 ~ 500 m
Pulleniatina oblicuiloculata	100 ~ 500 m
Globorotalia truncatulinoides	200 ~ 550 m
Globorotalia inflata	200 ~ 600 m
Globorotalia scitula	700 ~ 800 m

This data is essentially important in providing fundamental information for the paleoceanographic studies using oxygen and carbon isotopes of planktonic foraminifera.

PLANKTONIC FORAMINIFERS AS TRACERS OF OCEAN CURRENTS IN THE EASTERN SOUTH ATLANTIC

H. Oberhänsli (Univ. of Bremen, Germany), C. Bénier, G. Meinecke, H. Schmidt, R. Schneider, and G. Wefer

The standing stock of planktonic foraminifers collected at 16 stations by multinet plankton tow has been examined in five discrete depth intervals (0-25 m, 25-50 m, 50-100m, 100-150 m, 150-300m). The assemblages document the status of populations in the surface and subsurface waters of the Southeast Atlantic during February and March of 1988. Standing crops document hydrographic conditions in the coastal and geostrophic branches of the Benguela Current, the Angola Current and the Tropical Cyclonic Gyre, and the South Equatorial Current.

Standing stocks are highest when primary productivity is intermediate. Very high primary productivity reduces foraminiferal crops significantly.

Eleven species occur abundantly (average >10% of the total standing stock). A few species (*G. glutinata, G. quinqueloba/G. clarkei*) are abundant at each station whereas the occurrence of other species (*G. ruber, G. sacculifer, G. scitula, G. menardii, G. crassaformis, N. incompta, N. dutertrei*) is spatially restricted.

G. ruber, G. rubescens and *G. glutinata* are abundant in high-salinity surface water. Also, *G. ruber* is abundant within the Equatorial Undercurrent water, when this water is brought to the surface. High concentrations of *N. incompta* and *G. bulloides* are observed at the outer margin of the coastal branch of the Benguela Current when nutrient concentration is moderately elevated in surface and subsurface water (upper part of the thermocline). *G. crassaformis* is abundant in the subsurface water of the outer margin of the coastal Benguela Current. This species is restricted to less oxygenated subsurface water.

G. menardii is considered to be an indicator for the Equatorial Undercurrent below the mixed layer whereas the presence of *G. scitula* most likely suggests an admixture of water transported by the northward flowing Benguela Current. High abundances of *G. quinqueloba/G. clarkei* in the surface and subsurface waters reflect favorable nutrient conditions, like those present in the geostrophic Benguela Current and in the equatorial divergence zone. *G. falconensis, N. dutertrei*, and *G. siphonifera* appear to trace the Southern Equatorial Current.

LATE MIDDLE EOCENE BOTTOM WATER EVENT IN THE SOUTH ATLANTIC

H. Oberhänsli (Max-Planck-Institut, Mainz, Germany) and E. Müller-Merz

Bottom water environment evolved in the western and eastern South Atlantic during foraminiferal Zones P12-P13 and P14, respectively. The chronologic asymmetry is striking: the event occurred first in the western basin and then was proceeding to the eastern basin with a delay of about 1 to 2 Ma. The change in bottom water characteristics induced numerous last occurrence events in benthic foraminiferal assemblages. Re-adaptation affected primarily infaunal species, which disappeared exceedingly. Preservation of planktonic foraminifers deteriorated also, indicating progressive calcite undersaturation in the newly formed water mass below 2.5 km depth. Oxygen and carbon isotope signals of the newly formed water mass indicate increasing values.

We suggest that the water mass occupying intermediate and deep water settings originated in the perimeter of the Antarctic continent and evolved around 42 Ma in response to the progressive cooling in high latitudes.

JURASSIC THROUGH EARLY CRETACEOUS SEDIMENTATION HISTORY OF THE TROPICAL PACIFIC

J.G. Ogg (Dept. of Earth and Atmospheric Sciences, Purdue Univ., West Lafayette, Indiana, USA)

Sedimentation in the Central Pacific during the Jurassic and Early Cretaceous was dominated by abundant biogenic silica deposited under oxygenated bottom-water conditions at all depths, accompanied by pervasive oxidation of organic carbon and metals. Despite the more "equable" climate conditions of the Mesozoic, the super-ocean of the Pacific experienced adequate deep-water circulation to prevent stagnation. Radiolarian productivity rose to a peak within 5° of the paleo-equator, where accumulation rates of biogenic silica exceeded 1000 g/cm^2/m.y. Cyclic variations in the productivity of radiolarians and nannofossils and in the influx of terrigenous clay are attributed to Milankovitch climatic cycles. Diagenetic redistribution of silica and carbonate enhanced the expression of this cyclic sedimentation.

Clayey radiolarites dominated oceanic sedimentation within tropical paleolatitudes from at least the latest Bathonian through Tithonian. Wavy-bedded radiolarian cherts developed at sites in close proximity to the paleo-equator where radiolarian/clay ratios were high. Ribbon-bedded cherts appear to require primary alternations of radiolarian-rich and clay-rich layers as an initial structural template, coupled with abundant biogenic silica in both layers. Silicification processes in sediments which were extensively mixed by bioturbation or which were enriched in clay or carbonate generally resulted in discontinuous bands or nodules of porcellanite or chert.

Carbonate was not preserved on the Pacific ocean floor or spreading ridges during the Middle through Late Jurassic, perhaps due to an elevated level of dissolved carbon dioxide. During the Early Cretaceous, the carbonate compensation depth (CCD) descended to approximately 3500 m, permitting the accumulation of siliceous limestones at near-ridge sites. Carbonate accumulation rates exceeded 1500 g/cm^2/m.y. at sites above the CCD, yet there is no evidence of an equatorial carbonate bulge during the Early Cretaceous. The CCD rose in the Barremian and Aptian, coincident with the onset of mid-plate volcanic activity.

LATE QUATERNARY BENTHIC FORAMINIFERA CADMIUM RECORDS: WESTERN EQUATORIAL PACIFIC AND NORTH-WESTERN PACIFIC

N. Ohkouchi (Ocean Research Institute, Univ. of Tokyo, Nakano-ku, Japan), H. Kawahata, M.Okada, M. Murayama, and A. Taira

We report first benthic foraminifera Cd/Ca results of cores from the western equatorial Pacific (water depth: 2500m) and the northwestern Pacific (2700m) during the Late Quaternary.

The western equatorial Pacific time-series Cd/Ca record indicates that the deep water phosphate concentration during the last glacial maximum was 10-20% higher than that of modern deep water. On the other hand, the

northwestern Pacific time-series Cd/Ca record shows that the deep water phosphate concentration was the lowest during the early stage of deglaciation (15 kyr). At that time nutrient concentration was as low (1.1μmol P/kg) as the modern deep water in the North Atlantic, and it may suggest that the deep water formation occurred in the North Pacific.

We also report the nutrient vertical profile during the last glacial maximum in the western equatorial Pacific. It reveals that the phosphate concentration during the last maximum was higher than that of the Holocene by 0.4-0.7 μmol P/kg in the depth range between 1700m and 3800m.

LATE PLEISTOCENE $\delta^{13}C$ VARIABILITY IN THE WESTERN EQUATORIAL PACIFIC

M. Okada (Ocean Research Institute, Univ. of Tokyo, Japan), N. Ohkouchi, and A. Taira

We carried out oxygen and carbon isotope measurements for both benthic and planktonic foraminifers from calcareous deep sea core KH90-3 2PC (01°10'S, 160°01'E, 2494 m). Since this area is outside of the equatorial upwelling region, we can reconstruct surface $\delta^{13}C$ variability without nutrient-rich deep water effect.

The $\delta^{13}C$ contrasts between benthic and planktonic foraminifers show detailed changes of ocean surface productivity for the last 330Ka in the western equatorial Pacific region. This record is basically similar to the result from eastern equatorial Pacific (V19-30): high contrast during glacial periods and low contrast during interglacial periods. The comparison of this record with atmospheric pCO_2 record (VOSTOK ice core) indicates that increased surface productivity caused pCO_2 reduction at the end of the last interglacial. Although it also indicates that only half amount of the pCO_2 reduction until the last glacial maximum (LGM) was resulted due to the increased productivity. These results suggest that we must seek another reason except surface production for the LGM lower pCO_2.

MODELLING OF PELAGIC BIOGEOGRAPHIC PROVINCES

D.B. Olson (Rosenstiel School of Marine and Atmospheric Science, Univ. of Miami, Florida, USA), C.S. Davis, and G.R. Flierl

Models of the range of individual plankton species in the context of the ocean circulation are discussed. The object is to explore the degree of complexity required in a biological model to reproduce biogeographic boundaries. As a foundation for such models, a traditional nutrient, phytoplankton, zooplankton and detritus (NPZD) model is used. The approach uses the NPZD to simulate the biological environment in which a species lives. A more specific population model is then embedded that treats the distribution of the species of interest. In particular the nature of population boundaries and the role of physical versus biotic control of these features are considered. Examples displayed are populations in proximity to the edge of the Gulf Stream and idealized gyre structures. In addition to models of population density, methods of treating population genetics are briefly considered.

GLACIAL TO INTERGLACIAL, BASIN TO SHELF PARTITIONING OF $CaCO_3$ AND ITS EFFECT ON ATMOSPHERIC CO_2

B.N. Opdyke (Dept. of Geological Sciences, Univ. of Michigan, Ann Arbor, USA) and J.C.G. Walker

Glacial to interglacial variation in the rate of coral reef carbonate deposition and carbonate bank erosion from the Pleistocene to the Holocene may account for differences in the atmospheric CO_2 content record in polar ice. Volumes of carbonate associated with Holocene reef deposition require an average deposition of 2.0×10^{13} mole/yr for the last 5 ka.

Combine riverine, mid-ocean ridge, and ground - water fluxes of calcium to the oceans are approximately 2.3×10^{13} mole/yr, therefore the current flux of calcium carbonate to pelagic sediments must be far below the Pleistocene average of 1.2×10^{13} mole/yr. It is assumed that direction and rate of sea-level change shifts the locus of carbonate deposition from the deep sea to the shelves and dictates the glacial-interglacial pattern of deposition for Quaternary global carbonates. A simple numerical simulation of the global carbon cycle was developed to assess the impact of these changes on atmospheric CO_2. Calcite saturation depth - sediment responses to these carbonate deposition changes are also examined. Atmospheric CO_2 changes close to those observed in the Vostok ice core, approximately 80ppm CO_2, for the Quaternary are observed, as well as the relative depth changes in percent carbonate of sediments measured in the Pacific Ocean over the same time.

MID-DEPTH CIRCULATION OF THE SUBPOLAR NORTH ATLANTIC DURING THE LGM

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Previous studies have shown that during the Last Glacial Maximum (LGM), the mid-depth (<2 km) North Atlantic was more nutrient-depleted than it is today (e.g. Boyle and Keigwin, 1987). Here we present new benthic foraminiferal $\delta^{13}C$ values were as high as 1.5‰ in the two shallower cores (1139 and 1326 m). Our data preclude the existence of an upwelling cell of low $\delta^{13}C$ Southern Ocean Water (SOW) in the subpolar North Atlantic as hypothesized in some earlier studies (e.g., Duplessy et al., 1988).

The data also suggest that the oxygen-minimum water present in the study area today at 1km was absent or shallower during the LGM; its absence is consistent with a better-ventilated thermocline during the LGM (Slowey and Curry, 1992). In conjunction with published data, our data indicate that the deeper reaches of the southeastern Rockall-Hatton Bank contained a large component of low-$\delta^{13}C$ Eastern Basin Water (EBW) during the LGM. $\delta^{13}C$ values decreased by as much as 0.8‰ from 2000 to 2300 m.

PLANKTIC FORAMINIFERS IN MOCNESS TOWS FROM THE CALIFORNIA CURRENT DURING SEPTEMBER 1990

J.D. Ortiz (College of Oceanography, Oregon State Univ., Corvallis, USA), A.C. Mix, and R. Collier

We analyzed depth stratified MOCNESS plankton tows from three transitional sites at 42°N across the California Current. These plankton tows, collected across strong hydrographic gradients, yield three distinct foraminiferal distributions: 1) Cool water/ transitional species present in the mixed layer or thermocline at all sites, 2) Warm subtropical species that decreased in abundance toward the coast, and 3) Species apparently dwelling at depths from 200 to 600 m.

The species of planktic foraminifers were found to inhabit different depth zones at the three sites, probably in relation to changes in hydrographic conditions. Foraminiferal standing stock and plankton biomass (>63 μm) were concentrated in the mixed layer (<30 m) at the sites 130 km ("Nearshore") and 280 km ("Midway") from the coast. In contrast, at the site 650 km from the coast ("Gyre") both foraminifers and plankton biomass (>63 μm) were found largely within the thermocline (30-70 m).

At "Nearshore" and "Midway", the majority of the surface dwelling foraminifers were small individuals of "cool" water taxa, as defined by published core top studies. These species were *N. pachyderma* (R), *G. quinqueloba* and the P-D intergrade category. The low salinity water of the Columbia River plume sampled at "Midway" was associated with low foraminiferal standing stocks and a shift in the ratio of "cool" to "warm" species. The freshwater plume should influence the sedimentary record observed at these sites.

The offshore foraminifer community at the "Gyre" site was dominated by large, thermocline dwelling individuals of the species *N. dutertrei*, *O. universa* and the "cool" water species *N. pachyderma* (R), *G. quinqueloba* and the P-D intergrade category. Yet, surface dwelling individuals of "warm" water taxa such as *G. ruber*, and *G. glutinata* were also present at this site. This suggests that species-specific depth stratification may be as important a source of variation at these transitional sites as temporal and mesoscale variability. Three species of foraminifers were found in greatest numbers at depths between 200 and 600 m, these species were *N. pachyderma* (L), at "Nearshore", *G. hexagona* at "Gyre" and *G. scitula* at all three sites. These deep-dwelling species may be useful recorders of sub-thermocline conditions in the geologic record.

GLACIAL/INTERGLACIAL BENTHIC FORAMINIFERA IN THE NORWEGIAN SEA, ODP SITE 643

L. Osterman (Geology Dept., George Washington Univ., Washington, D.C., USA)

ODP Site 643 shows a long record of glacial and interglacial fluctuations extending back to 2.56 Ma. Using sediment and biological data the glacial history of the Norwegian Sea can be divided into three main periods.

From 2.56 to 1.2 Ma the Norwegian Sea was characterized by extreme dissolution and the absence of all foraminifera. Early Pleistocene calcite dissolution was due the influx of cold, low-salinity surface water which prevented oceanic overturning. The lack of deep water ventilation and increased input of resuspended organic matter to the basin resulted in low carbonate productivity and increased bottom water CO_2 (Henrich, 1989). Limited amounts of IRD during this time suggest a small persistent ice cap with no seasonality.

The transition to larger episodes of glaciation took place from 1.2 to .6 Ma (stage 15). Based on IRD, this transitional period was characterized by small persistent ice caps and warmer, but still cool, interglacials. Limited influx of warm NADW resulted in increased calcite preservation, and also permitted the growth of a small Scandinavian ice sheet. At Site 643, the bottom waters show a strong Arctic influence with *Stetsonia* found abundantly during the weak cool interglacials. Another Arctic species *Brizalina arctica* is common during glacials. The fact that both these species are small-sized Arctic endemics suggests that the Arctic Ocean interchange was dominant and the North Atlantic only weakly penetrated into the Norwegian Sea during this time. Striking similarities exist between the Norwegian Sea and the Arctic Ocean record (Scott et al, 1989), with both oceans experiencing full glaciation and calcareous foraminifera after 1 Ma. The global nature of cooling at this time supports a tectonic cause (Ruddiman model).

Only during the last 600,000 years has the Norwegian Sea climatic system varied in the manner described in previous studies of the Late Quaternary with strong cold glacials (Arctic influence) and strong warm interglacials (North Atlantic influence). Benthic foraminifera in this interval are characterized by *Stetsonia* in the glacials (Arctic) and *E. umbonatus* (North Atlantic) during the interglacials. This glacial-interglacial shift is seen most strongly during oxygen isotopic stages 14-13, 12-11 and 6-5.

PLANKTIC FORAMINIFERA AS INDICATORS OF OCEAN ENVIRONMENTS IN THE NORTH-EAST ATLANTIC

J.J. Ottens (Geomarine Center, Amsterdam, The Netherlands)

Within the framework of APNAP (Actuomicropaleontology Paleoceanography North Atlantic Project) surface water masses and their characteristic planktic foraminiferal assemblages have been determined for two seasons, oceanic summer (1986) and early spring (1988). Frontal zones, which often border these water masses, can be recognized in a higher number of species resulting from mixing of adjacent water masses. However, in the highly unstable spring period absolute frequencies (productivity) and information indices (diversity) proved to be better suited to characterize the ocean environment than planktic foraminiferal assemblages.

Species depth stratifications cannot be directly related to thermocline depth and the presence or absence of a deep chlorophyll maximum (DCM). Commonly abundant species, such as *G. bulloides*, *N. incompta*, *G. inflata*, *G. glutinata*, and *T. quinqueloba*, reach their highest frequencies in regions, where no DCM is developed. In regions with a well-developed DCM, their number remain relatively low, and they mainly prefer depths below or within this zone, except for *G. bulloides*. Furthermore, the so-called cosmopolitan *G. glutinata* appears to be more favored by an eutrophic environment, than *G. bulloides*, which is commonly used as indicator for nutrient-rich waters.

Ocean environments can also be characterized by the number of species (simple diversity), an information function (Shannon diversity), and a measure of equitability. Variable environments, such as the highly productive spring bloom and upwelling, are characterized by relatively low diversity and equitability values. Relatively high diversity, but intermediary equitability is found in mixing zones (fronts) of adjacent water masses. Under extreme conditions, such as the hypersaline, oligotrophic Red Sea, diversity is low, whereas equitability is intermediate to high.

DISSOLVED ORGANIC MATTER AND THE GLACIAL-INTERGLACIAL pCO_2 PROBLEM

D. Paillard (Centre des Faibles Radioactivités, Gif/Yvette, France)

Two extremely simplified models are described in order to investigate the effect of oceanic circulation changes on the atmospheric CO_2 concentration. Since a number of oceanic carbon cycle models have failed to reproduce the 30% increase in CO_2 partial pressure (pCO_2) during the last deglaciation as reconstructed from polar ice cores, we examine the effect of long-lived dissolved organic matter on the system. Carbon is usually assumed to be transported from the surface into the deep ocean through the sedimentation of particulate matter. If there exists in the ocean a pool of dissolved organic matter (DOM) with a regeneration time comparable with the advection time, then the associated carbon can also be advected, resulting in a different distribution. Such a DOM reservoir is known to act as a smoother on the spatial distribution of nutrients in the sea, particularly in the intermediate waters. We establish the role of intermediate waters as one of the key components of the oceanic carbon cycle and show that DOM reduces the sensitivity of carbon cycle to oceanic circulation-pattern changes, mainly because of its smoothing effect. Consequently, the possible existence of DOM species with a time constant of the order of a century tends to reduce, rather than enhance, the glacial-interglacial difference in pCO_2 levels due to changes in the thermohaline circulation.

BERMUDA CORAL REEF RECORD OF THE LAST 1000 YEARS

J. Pätzold (Universität Bremen, Germany) and G. Wefer

Long continuous chronologies of Bermuda coral growth give a high-resolution marine record for the subtropical North Atlantic over the past 1000 years. Coral growth band chronologies give a precise time scale on an annual scale. The thickness of the annual coral growth bands closely correlate with the historical average annual temperature records, i.e., the annual growth inversely correlates with temperatures.

Seasonal climatic information is recorded by variations in the ratios of stable oxygen and carbon isotopes. The stable oxygen isotopic record of corals reflects seasonal sea surface temperatures, despite an offset from equilibrium conditions, and the stable carbon isotopic record reflects changes in the respiratory and photosynthetic activities of the organisms and is thus linked to insolation variations. The resolution of this technique is of about 2 - 3 weeks in Bermuda corals with annual growth rates of about 3 mm/year.

The history of the European climate over the last 1000 years is characterized by different periods, showing as extremes the Medieval Warm Epoch from about 1150 to 1300 with mild wet winters and very warm dry summers, and the so-called Little Ice Age from about 1550 to 1700 with very cold dry winters and cool wet summers. However, considerable differences in timing were observed from place to place in the proxy data and the correlation to the marine record is not well known.

The Medieval Warm Epoch, a prominent feature in the European - North Atlantic sector, is reflected in the coral chronology by a short period around 1300. During the period of the Little Ice Age from AD 1500 and 1700 the coral

growth record shows large variability. Both annual growth band thickness and stable oxygen isotopes reflect the known worldwide temperature rise since the turn of this century.

MARINE BARITE AS A POTENTIAL RECORDER OF PALEO-MARINE CHEMISTRY

A. Paytan (Scripps Institute of Oceanography, UCSD, La Jolla, CA , USA), M. Kastner, E. Martin, and T. Herbert

The records of Sr, Nd and S isotopic compositions of seawater through time contain important information about climate, tectonics, submarine hydrothermal activity and oceanic circulation. Are there marine solid phases that reliably record and preserve these original isotopic compositions? The phase most commonly used for paleoceanographic studies, calcite, is known to undergo recrystallization upon burial. This process often changes its chemical and/or isotopic composition, resulting in less reliable data with increasing geological age. Therefore, identifying another redundant, but diagenetically more stable, phase is desirable.

Marine barite, a widespread component of pelagic sediments, may be such a phase. Barite occurs in the sediment and water column as very fine, 1-5 μm, ellipsoidal microcrystals. The exact mechanism and depth(s) of formation of marine barite is unknown. Much of it is preserved in oxygenated sediments since pore waters rapidly become saturated with respect to $BaSO_4$. Barite is relatively insoluble and therefore should resist diagenetic exchange.

A multiple-step dissolution procedure was employed in order to isolate barite from other sediment constituents. The separated marine barite was analyzed for Sr as well as S and Nd isotopic compositions. Preliminary results indicate that the $^{87}Sr/^{86}Sr$ ratio of marine barite from core tops reflect the modern seawater Sr isotopic ratio. The S and Nd isotopic analyses are in progress, preliminary results are expected before the meeting.

The S and Nd isotopic ratios of recent marine barite could also shed light on the precipitation depth(s) and formation mechanisms of barite. Since ξNd changes with water depth, comparing the barite and seawater ξNd at the same site might reveal its formation depth. S isotopic measurements may provide information regarding the S source for barite formation, i.e., whether the S is derived from dissolved SO_4^{2-} or organic matter, as has been suggested.

Marine barite may thus be a new reliable and stimulating phase for chemical paleoceanographic studies.

TEMPORAL VARIATIONS OF METEOROLOGICAL FEATURES IN A TROPICAL COASTAL REGION - SOUTHEAST COAST OF INDIA

P. Perumal (Center of Advanced Study in Marine Biology, Annamalai University, Parangipettai, Tamil Nadu, India)

Data on the monthly and annual variation of rainfall at Parangipattai, Southeast coast of India, for a period of two and a half decades is presented and the impact of rainfall on the hydrographical and biological features is discussed. Generally, the bulk of precipitation occurs during the northeast monsoon spread during October to December. Wind velocity data is also given and its influence on other parameters is discussed.

DETECTION OF MAGNETIC BACTERIA IN DEEP-SEA SEDIMENTS - DEPENDENCE ON GEOCHEMICAL PARAMETERS

H. Petermann (Universität Bremen, Germany) and U. Bleil

Magnetic bacteria synthesize intracellular magnetite crystals of characteristic shapes in a narrow grain size distribution. These crystals have repeatedly been found in deep-sea sediments where they occasionally constitute the dominant carrier of the remanent magnetization.

During RV METEOR cruise M20/2 to the eastern South Atlantic in early 1992, for the first time living magnetic bacteria were identified in pelagic and hemipelagic sediments. Different morphologies were observed in water depths to about 3100 m on the African continental margin between about the equator and 30 °S but also on a Walvis Ridge seamount 1500 km off the coast. In deeper waters no actively swimming magnetic bacteria could be detected whereas their magnetic particles (magnetosomes) were also present in the sediments of several deeper sites. Maximum concentrations of magnetic bacteria revealed a significant dependence on water depth. Close to the African coast in water depths down to about 1000 m even larger populations were found than in intertidal sediments (mud flats) of the North Sea.

Magnetic bacteria only occurred in the upper 10 cm of the sediments, maximum concentrations always in a well-defined narrow subsurface layer between 1 and 4 cm depth in the sediment. Within a few centimetres below this level their number gradually decreases to zero. Measurements of oxygen and nitrate concentrations provide an assignment of these depth distributions to the stratification of terminal electron acceptors in the sediment. The data clearly show that the large majority of magnetic bacteria live in the anaerobic zone, in contrast to former assumptions that they may indicate a microaerobic layer.

NEOGENE CARBONATE ACCUMULATION AND COMPENSATION DEPTH CHANGES IN THE INDIAN OCEAN

L.C. Peterson (RSMAS, Univ. of Miami, FL, USA) and D.W. Murray

Quantitative estimates of the flux of biogenic carbonate to the sea floor, and of the rates and patterns of its subsequent accumulation, are key components to understanding past ocean history. We have compiled data on carbonate mass accumulation rates (MARs) for sites occupied during the nine-leg campaign of Indian Ocean drilling by ODP. Regional accumulation patterns are found that are variably affected by the changing balance between productivity and dissolution, and by physical processes such as erosion. In the early and middle Miocene, greatly reduced carbonate accumulation in the equatorial region is the result of a shallow CCD and a probable drop in surface productivity. Winnowing was also common at shallow Indian Ocean sites during this interval, suggesting a more vigorous intermediate water circulation. At about 8-9 Ma, carbonate accumulation rose abruptly at shallow low-latitude sites because of increased biogenic production. At the same time, an enhanced contrast in depth-dependent carbonate accumulation indicates that a strong dissolution gradient was first established in the water column. Carbonate accumulation dropped at about 3 Ma, but remained at levels well above those of the early-middle Miocene. Over the last 8 m.y., Arabian Sea sites show

carbonate accumulation patterns similar to shallow sites from the tropical Indo-Pacific region far removed from the direct influence of monsoonal upwelling. Although faunal and floral evidence from Leg 117 support an increased monsoonal circulation near 8 Ma, our data suggest that carbonate deposition in the northwestern Indian Ocean is responding more to global-scale processes than to the localized influence of the monsoon.

A comparison of the Neogene depth history of the CCD to carbonate MAR records at shallower sites reveals a lack of direct correspondence between MAR variations and CCD motion. This lack of correspondence implies that the respective controlling processes are uncoupled, with shallow carbonate accumulation more likely related to changes in regional surface fertility, and the CCD itself responding to a forcing that is more global in nature (e.g., sea-level or mean Ca^{+2} concentrations).

SIMMAX, A TRANSFER TECHNIQUE TO DEDUCE ATLANTIC SEA SURFACE TEMPERATURES FROM PLANKTONIC FORAMINIFERA - THE EPOCH APPROACH

U. Pflaumann (Geological-Paleontological Institute, Kiel, Germany), C. Pujol, M. Duprat, and L. Labeyrie

The CLIMAP transfer function was highly successful in generating a SST data base that led to a revolution in the concepts of global climatic change. However, this technique suffered from significant deviations of the past species assemblages from the modern fauna, so-called 'no-analogue sample,' that do not fit in the modern SST regression model and hence may cause data gaps and a reduced resolution in many sediment records from the deep sea. Moreover, the selection of the faunal end members, the 'factors,' as base for the regression is arbitrary and biased to some extent. Recent work by US colleagues (e.g., Molfino, McIntyre, Prell) overcame these problems using the new Modern Analogue Technique (MAT), based on the degree of similarity between fossil and modern faunal assemblages in a specific SST field.

The new EPOCH transfer technique follows this approach and is based on a joint EPOCH set of 769 genuine sediment surface samples from the Atlantic between 85°N and 40°S, 30°E and 60°W selected from the Kiel, Bordeaux, and CLIMAP scores. These data are linked to Levitus modern SST data for the four caloric seasons and four depth ranges. The linear correlation coefficients between estimated and measured caloric winter and summer temperatures of the sea surface are above 0.99 with standard deviations of 0.85°C at 0-5 m and 0.94°C for the deeper layers down to 75 m water depth.

The results form the EPOCH transfer technique will provide record i) to be compared with U_K^{37} -based temperature data from the very sea surface, ii) to reconstruct the variations in the thickness of the ocean mixed layer, and iii) to decipher the temperature component in the planktonic $\delta^{18}O$ records for deducing paleosalinity.

RECENT EUSTATIC VARIATIONS

P.A. Pirazzoli (CNRS, Laboratoire de Géographie Physique, Meudon-Bellevue, France)

Following Gutenberg (1941), who was the first to publish an estimation of the recent eustatic variations worldwide from tide-gauge records, various authors attempted a similar evaluation. Three main approaches have been used. The first approach, common to most early studies, consisted mainly of using various kinds of averaging methods applied to uncorrected data, after exclusion however of record series considered doubtful or coming from areas regarded as uplifting or tectonic, but not excluding wide areas which are now known to be of moderate subsidence. This attempt, which obtained average values of sea-level rise ranging mainly from 1.0 to1.5 mm/yr is methologically biased towards a rise value larger than the eustatic one.

A second approach consisted of "correcting" the primary data, using geological data, climatic correlations or geophysical isostatic models. This second attempt gave more variable results (a computed sea-level rise from 0.5 to 2.4 mm/yr), with however greater values (1.7 to 2.4mm/yr) when stations from the east coast of North America (where the rate of relative sea-level rise is generally faster than in other coastal areas of the Atlantic) are predominant in the sample of tide-gauge stations considered.

The third group of studies was unable to assign any reasonable estimate to the present rate of eustatic rise of sea-level, despite the evident need for such an estimate and the effort to determine that rate. This was caused by the identification of a loud background noise (due to meteorological, hydrological, tectonic and anthropic factors) which prevents accurate global assessments.

Two important points on which general agreement is emerging are: (1) no author claims that the eustatic sea-level has been dropping during the last century, and (2) in spite of increasing concentrations of "greenhouse" gases in the atmosphere, no evidence can yet be found for mean sea-level acceleration.

TEMPORAL RESPONSE OF THE EAST PACIFIC CARBONATE SYSTEM TO ORBITAL FORCING: EVIDENCE FROM SITE 849 LEG 138

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L. Mayer, N. Shackleton, T. Hagelberg, A. Mix, and ODP Leg 138 Shipboard Scientific Party

The continuous, astronomically calibrated GRAPE density records from the ODP Leg 138 sites (see Hagelberg et al. and Shackleton et al. posters) provide the opportunity to examine the temporal response of the Eastern equatorial Pacific carbonate system to orbital forcing. Using shipboard measurements of %$CaCO_3$ we have converted GRAPE density to %carbonate for all sites. We show evolutive spectra for the past six million years over which the timescale is well constrained, together with cross-spectra against insolation

Over most of the record, low percent carbonate is associated with more positive $\delta^{18}O$ The detailed development of the timescale leads us to conclude that at least in the sites close to the equator in which peak sedimentation rates approach or exceed 10 cm/ka, low percent carbonate is driven primarily by enhanced opal flux rather than by increased carbonate dissolution (see Hagelberg et al poster).

The application of detailed time series analyses including cross-spectral analysis, evolutive spectra and complex demodulation reveal an evolving response of the equatorial Pacific system over the past six million years. For example, the analyses reveal clear breaks in the relationship between carbonate and isotope records at about 800ka, and at about 1.6Ma. The break at 800ka is clearly associated with the onset of 100ky cycles in the $\delta^{18}O$ record. A similar increase in 100kyr power in carbonate is not observed. This transition is characterized by a significant change in the phase relationship between carbonate content and forcing in the obliquity band.

This observation has important implications with respect to the strategy used to develop high resolution chronologies for Leg 138 drill sites. The chronology was developed by assuming a constant phase relationship between carbonate content and summer solar insolation at 65°N. Even though this insolation record contains an obliquity component the chronology did not force an absolute phase lock for carbonate content at the 41ky frequency. The chronology does, however, result in a relatively constant phase between $\delta^{18}O$ and insolation. However, the changes in the phase between carbonate content and climate can be directly estimated from the the phase relationship between carbonate and $\delta^{18}O$, which is not dependent on the details of the chronology.

LAND-SEA CORRELATION OF THE LAST 25,000 YEARS OF THE SVALBARD/ BARENTS SEA AND EAST GREENLAND MARGIN: PRELIMINARY RESULTS

PONAM/CLAMD Working group (c/o Anders Elverhøi, Dept. of Geology, Univ. of Oslo, Blindern, Norway)

A main objective under the PONAM program (Polar North Atlantic Margin, Late Cenozoic Evolution) is to link the terrestrial and the marine records. To test such a concept, the evolution of the Norwegian-Greenland Sea, and its adjacent margins of East Greenland and Svalbard/Barents Sea during the last 25,000 years, are being investigated.

Two transects across the Norwegian-Greenland Seas: from Jameson Land/Scoresby Sund (Greenland) to Isfjorden/-Spitsbergen and from Jameson Land/Scoresby Sund to Bear Island Trough/SW Barents Sea have been selected. On the basis of oxygen isotope stratigraphy combined with AMS-dating, an absolute chronology has been established, and the correlation will be undertaken for the following time slices: 23 ka, 18 ka, 15 ka, 13.5 ka, 12.5 ka, 11.5 ka, 10.5 ka, 8 ka, and 5 ka.

Preliminary results have demonstrated that the number, composition and distribution of the peaks of terrigenous material, as indicated by high percentage of coarse (> 500 μm) lithogenic material and a certain amount of terrigenous matter found in the deep sea, continental slope and shelf sediments during oxygen isotope stages 2 and 1, can be correlated with the onshore glacial record in the Svalbard/Barents Sea region. The terrigenous input shows relative maxima at the early phase of isotope stage 2 and at the transition between stages 2 and 1, respectively. The first phase of ice recession from Svalbard, AMS dated to have occurred around 15 ka, is characterized by low sediment discharge into the adjacent deep sea, while the main phase of deglaciation, culminating at 12.5 ka, caused a high input of terrigenous material into the ocean and outer shelf. This peak shows regional and time variations in composition, reflecting the ice oscillations onshore. At the moment, we have no signal for a Younger Dryas re-advance of the Svalbard/Barents Sea-Ice Sheet.

RADIOLARIAN ASSEMBLAGES AS INDICATORS OF TRANSGRESSIVE AND REGRESSIVE PALEOBASIN PHASES (ON THE BASIS OF RESULTS IN THE SAKHALIN AREA)

I.M. Popova (Far East Geological Institute, Vladivostock, Russia)

Results of Renz (1976), Takahashi and Honjo (1981), Anderson (1983, 1989), Boltovskoy (1988), Caulet et al. (1991) and many other workers have shown that radiolarian sedimentary assemblages allow interfering not only with upwelling conditions and the depth at which the living organisms dwelled, but also recognize associations characteristic of shelf areas, bathyal and abyssal habitats. Dominance of *spongodiscids* in the assemblages, in association with lithologies represented by fine-grained sandstones, suggest that the corresponding deposits were formed in a shelf environment. Dominance of *Spongodiscidae* and *Larcoidea* in aleurites point at formation in the bathyal zone; while representatives of the above two families are scarcely represented in a taxonomically diverse assemblage, and the rocks in which they occur are aleurites or diatomites - the corresponding paleoenvironment was most probably abyssal.

Radiolarian data from four Neogene sections collected in Skhalin were used for generating curves reflecting the transgressive and regressive phases of this paleobasin. Lithological analyses of Miocene - Pleistocene rocks (conglomerates to diatomites), and alternation of macro- (plants) and microfossils (radiolarians, diatoms and benthic foraminifers) suggest numerous (up to 20) cycles in the water-level of the paleobasin. These cycles include both local and global events. Global events were investigated comparing the present data with similar results from northern and southern Sakhalin, and with literature reports from the Kurul Islands, the Japanese Islands and Kamchatka. My results indicate that maxima in these global transgressions (Sakhalin and adjacent territories of the island arc) occurred at the Early-Middle Miocene boundary, in the second half of the Late Miocene and in the Early Pliocene. Regressions were centered on the second half of the Middle Miocene, the first half of the Late Miocene and in the Late Pliocene.

SUBSIDENCE AND SEDIMENTARY HISTORY SOUTH-WEST OF THE FAEROE ISLANDS

J. Posewang (Institute of Geophysics, Christian-Albrechts Univ., Kiel, Germany) and F. Theilen

The evolution of the area southwest of the Faeroe Islands has mainly been influenced by massive volcanic extrusions in the Late Paleocene. Lava flows propagated from the Faeroe Islands in a southwesterly direction. They are now covered by sediments of Eocene age and younger.

During the Eocene, a number of seamounts, intrusive and extrusive centers developed in this area. Reflection seismic investigations have been carried out on two of these features: the Bill Bailey and the Lousy Bank. Seismic data show two lavaflows of different origin and flow direction below the Lousy Bank, which is suggested to be an extrusive center.

The analysis of the sedimentary structures reveals that the top of the banks are void of sediment. Deposition is concentrated in the trough between the two banks and the surrounding areas. Onlap structures evidence the crustal subsidence between the banks, erosional horizons mark sea level changes and downlap structures document the direction of sedimentation and changes in sediment transport within this region due to the subsidence of the Iceland-Faeroe Ridge. The transition between the banks and the Iceland-Faeroe Ridge is characterized by a thin cover of sediments and a small trough associated with the Faeroe Bank Channel.

DO PALEO-CLIMATIC RECORDS EXHIBIT THE HURST PHENOMENON?

G. Poveda (Postgrado en Aprovechamiento de Recursos Hidráulicos, Universidad Nacional de Colombia, Medellin, Colombia)

Five high-resolution, paleo-climatic time series spanning the last 3.2 million years are analyzed: benthic foraminiferal $\delta^{18}O$, $\delta^{13}C$ and estimated sea-surface temperature reconstructed from deep-sea cores from the Atlantic Ocean. This set of time series is used to develop standard statistical analyses: auto-correlation function, variance function, scale of fluctuation, and power spectrum.

Our main goal is to search for: a) the existence of the Hurst phenomenon and b) convergence to Brownian motion. These tasks are accomplished using a new test developed by Mesa and Poveda (1992), with the aid of the so-called GEOS diagrams. It is concluded that the time series exhibit the Hurst phenomenon due to non-stationarity of the record. A notable exception is found for the ^{18}O record for the last 700,000 years, which does not exhibit the Hurst phenomenon and, therefore, there is convergence to Brownian motion, for this time series which has an estimated scale of fluctuation of 15,000 years.

BIOMARKER PERSPECTIVE ON OCEANOGRAPHIC CHANGES IN THE NORTHEAST PACIFIC DURING THE LAST GLACIAL-INTERGLACIAL TRANSITION

F.G. Prahl (College of Oceanography, Oregon State Univ., Corvallis, USA), M.A. Sparrow, and B. Eversmeyer

A core (W8709A-8TC) was collected 270km offshore at 42°N in the northeast Pacific Ocean and analyzed stratigraphically for elemental (TOC, C/N), isotopic ($\delta^{13}C$ of TOC) and selected biomarker composition. TOC accumulation rates increased two-fold from glacial to interglacial intervals. Organic matter composition was not homogenous throughout the profile but displayed significant variations in C/N and $\delta^{13}C$ composition and plant wax lipid (n-alkanes, n-alcohols, n-acids) concentration (/gC). This implies temporal changes in the terrestrial to marine contribution to TOC. The stratigraphic trends for each property are not all consistent, however. Maximum terrestrial contributions are inferred during the glacial/interglacial transition (15-10 Ka) for C/N and $\delta^{13}C$ data and during the glacial interval for plantwax lipid data. None-the-less, marine contribution to TOC appears predominant in all geochemical assessments.

Long-chain alkenone concentrations (/gC) decreased 50% during the glacial/interglacial transition. This behavior is not explained by recognized diagenetic effects on alkenones relative to TOC and implies a decrease in the importance of prymnesiophyte production relative to total primary production in recent times. Temperature estimates made from analysis of $U_K{}^{37}$ values in the alkenone series depict a sea-surface warming from 7-8°C in glacial times to 11-12°C today. The qualitative and quantitative features of the profile closely match downcore estimates of sea-surface temperature made by a completely independent analysis of radiolarian species assemblages in the same core. These organic geochemical findings support the views of others that the contemporary position for divergence of the West Wind Drift into northward and southward flowing boundary currents and of coastal upwelling off northern California/Oregon/Washington is significantly different from that prevailing in this region during the last glacial period.

DRILLING ATOLLS & GUYOTS (ODP LEG 144): PRELIMINARY RESULTS AND OCEANOGRAPHIC IMPLICATIONS

I. Premoli-Silva (Dipartimento di Scienze della Terra, Università di Milano, Italy), J.A. Haggerty, and the Scientific Staff of Leg 144

Drilling during Ocean Drilling Program Leg 144: Atolls and Guyots was arranged along a S-N transect (Marshall Islands, Japanese Seamounts Province, and MIT Guyot) to investigate if trends existed in the development of guyots, and in the causes and the timing of the carbonate platform demise.

All the guyots are resting on old oceanic crust, mainly mid to Late Jurassic age, with the exception of Takuyo-Daisan (Seiko) which rests on crust that formed during the earliest Cretaceous. The summits of the guyots are 1000 and 1500 mbsl; the guyots have several km relief from the surrounding basins. The volcanic construction of these edifices, which presently lie north of the equator, occurred in the southern hemisphere between about 30°S and 10°S.

The majority of these guyots experienced a volcanic episode between the Barremian and early Aptian time, which brought the volcanic edifices above sea level. During the subsequent subsidence ot the volcanic edifice, a carbonate platform developed. These guyots drowned by the end of the Albian since calcareous plankton of latest Albian age is embedded in the overlying manganese crust.

Guyots in the Marshall Islands experienced a volcanic event during late Santonian-early Campanian which resulted in an uplift to the photic zone. Some of them became an atoll with immer lagoon to reef to fore-reef environments, including constructional features rimming the edges of the platform by mid-Maastrichtian time. These platforms drowned before the end of the Maastrichtian, since pelagic sediments of Late Cretaceous age infill cavities at the top of carbonate material.

The main difference between the mid-Cretaceous and the Late Cretaceous shallow-water platforms is that the former are more similar to the Bahamian bank style of carbonate platform, whereas the latter are more similar to the modern Pacific atolls. The benthic community shows a marked difference: the Aptian-Albian assemblages are dominated by cosmopolitan species and include several species described from even the northern side of the Tethys; the assemblages from the Late Cretaceous are dominated by faunas of the Caribbean province with few cosmopolitan species or species of Tethyan affinity. This difference implies that a change occurred in the oceanographic regime from an eastward to a westward current system.

LATE QUATERNARY PALEOCEANOGRAPHY OF THE SOHM ABYSSAL PLAIN: BENTHIC FORAMINIFERAL ASSEMBLAGES, TOTAL CARBONATE AND STABLE ISOTOPE EVIDENCE

A. Putar-Roberts (Center for Marine Geology, Dalhousie University, Halifax, Nova Scotia, Canada) and D. B. Scott

Piston cores from the Newfoundland Slope (2200m water depth), the Nova Scotia Rise (4492m water depth) and the central parts of the Sohm Abyssal Plain (4974m water depth) were examined for various paleoceanographic proxies (benthic foraminifera, stable isotopes, total carbonate). As expected the three localities show markedly different stratigraphies. However, all these cores penetrate through the last glacial sediments (stage 2) into older non-glacial sediments (stage 3 or stage 5). The slope and rise cores are the first piston cores from this margin that penetrate through the stage 2 glacial sediments.

In all three sites there is evidence of Arctic Bottom Water (as defined by the presence of *Stetsonia arctica*). At the shallowest site (2200m) the Arctic Bottom Water appears towards the end of last non-glacial period. At the two deeper sites Arctic Bottom Water occurs in the early Holocene but is quickly replaced by more typical deep-water assemblages (i.e. either agglutinated or *Nuttallides umbonifera*). The *Stetsonia arctica* assemblage reoccurs in the older, non-glacial sediments.

As expected, the two marginal cores are dominated by turbidite sediment and are difficult to correlate with open ocean sites. However the approach used here has allowed some correlation, especially with bottom water events. Arctic Bottom Water appears to come in much later into deep North Atlantic than in the slope water area, at least in the Western North Atlantic. In the slope water area the carbonate curve, during the glacial, correlates with turbidites, not biologic production, as it does in the deep water sites. In the deepest site, from the Sohm Abyssal plain it appears to be up to 3 glacial-interglacial cycles, illustrating the thinning of the turbidite wedge as you get away from the Canadian Margin.

SHORELINE OSCILLATION STUDY USING SATELLITE DATA OF SOUTH-EAST COAST OF INDIA

N. Radhakrishnan (Institute of Remote Sensing, Anna Univ., Madras, India) and R. Krishnamoorthy

IRS LISS-II and SPOT satellite data of the Tamil Nadu coast were taken for a shoreline oscillation study. The study area is characterized by fluvio-marine activities and mainly of coastal progradation, rather than erosion. The formation of coastal strandlines, petal-shaped lakes in Vedaranyam and Ramnad coastal areas clearly show the migration of shoreline due to marine transgression during Cretaceous and to the recent period. The maps have been prepared to depict the evolution of the present coast using LISS-II and SPOT data.

MIOCENE TO PLEISTOCENE CALCAREOUS NANNOFOSSILS FROM THE EASTERN EQUATORIAL PACIFIC OCEAN (ODP LEG 138)

I. Raffi (Universita di Parma, Servizio Geologico Nazionale, Roma, Italy) and J.A. Flores

The calcareous nannofossil biostratigraphy and biochronology of the sedimentary sequences retrieved during ODP Leg 138 in the Eastern Equatorial Pacific Ocean are presented. In the sediments recovered from 11 sites, drilled along two north-south transects (95°W and 11°W), the calcareous nannofossil are generally common to abundant, and provide a detailed biostratigraphy of almost all the sedimentary sequences. In some of them, the Late Miocene to Late Pliocene time interval is characterized by siliceous clay sediments, and intervals with poor nannofossil contents are associated with this carbonate decrease. In spite of this, even in these sediment sections it has been possible to obtain a good biostratigraphic classification.

In the time interval from the late Early Miocene to the Pleistocene up to more than 35 nannofossil events have been recognized; these allow a detailed intersite biostratigraphic correlation. Most of them correspond to the zonal boundaries of the standard 1971 zonation of Martini and to the 1973 zonation of Bukry. Other secondary events, already proposed and discussed in the literature (Fornaciari et al., 1990; Rio et al., 1990; Olafsson, 1991; Fornaciari et al., in press; Raffi et al., in press), are recognized and used to improve the biostratigraphic resolution provided by the standard zonations.

LIVING (STAINED) BENTHIC FORAMINIFER FROM THE LOW-OXYGEN ENVIRONMENTS OF THE SULU SEA (PHILIPPINES)

A.E. Rathburn (Dept. of Geology, Duke University, Durham, NC, USA) and B.H. Corliss

Benthonic foraminiferal faunas containing abundant specimens of *Bolivina, Uvigerina, Bulimina, Globobulimina or Chilostomella* have been found in a number of areas in the oceans associated with high organic carbon content of the sediments and overlain by low bottom water oxygen conditions. The importance of low oxygen and high organic carbon content on living (Rose Bengal stained) benthic foraminiferal distributions is examined in the Sulu Sea, a silled marginal basin with relatively low (~1.25 ml/l) bottom water dissolved oxygen levels at all depths below 1,000 m. Vertical faunal patterns of the >150 µm fractions are compared with organic carbon contents, bottom water and pore water oxygen levels of 8 Sulu Sea box cores taken in water depths ranging from 510 m to 4,515 m.

The shallowest site (510 m) is dominated (>10% of the calcareous fauna) by *Cibicidoides and Uvigerina*, which are also co-dominant with *Siphonina* in the 1,005 m core. The 2,000 m core is dominated by *Cibicidoides, oridorsalis* and *Gyroidinoides*, while *Cibicidoides bradyi* and *Oridorsalis umbonatus* dominate the 3,000 m and 4,000 m cores. Infaunal assemblages of *Valvulineria mexicana* dominate the sediments of the 4,515 m core.

Shallow infaunal (0-2 cm) abundances of *Bolivina, Uvigerina,* and *Bulimina* are highest in the two shallowest cores (5l0 m and 1,005 m), where surficial organic carbon values (0.86% and 0.91%) are highest. These taxa are not present in significant numbers in the 2,000 m, 3,000 m, 4,000, and 4,515 m cores. Maximum abundances of *Chilostomella* and *Globobulimina* are found only within the sediments (2.5-10 cm), under very low pore water oxygen conditions in the 510 m, 1,005 m and 4,515 m cores where subsurface organic carbon values are highest.

The paucity of "low oxygen fauna" in deeper portions of the basin indicates that their distribution is not controlled by low oxygen conditions, but is instead regulated by organic carbon. These results indicate that fossil assemblages containing significant numbers of these "low oxygen taxa" reflect organic carbon contents of the sediments and cannot be used to asess ancient bottom water oxygen conditions.

MARINE SEDIMENTARY ORGANIC $\delta^{13}C$ AS A PROXY FOR OCEAN/ATMOSPERE CO_2 CONCENTRATIONS: RECENT OBSERVATIONS AND MODELS

G.H. Rau (Institute of Marine Sciences, Univ. of California, Santa Cruz, USA)

Theoretical considerations, laboratory experimentation, and field observations show that the $\delta^{13}C$ of plankton organic biomass decreases as the concentration of ambient molecular CO_2, [CO_2, (aq)], increases. This argues that the $\delta^{13}C$ of plankton (and the suspended and sedimentary organic remains thereof) can be used as a proxy for ocean/atmosphere [CO_2]. For example, a recent compilation of available data shows that approximately 90% of modern-ocean plankton $\delta^{13}C$ variations can be explained by a simple negative linear relationship with [CO_2 (aq)]. The slope of the best-fit line is -0.6 (±0.01‰ μM^{-1}). A significant amount of the residual variability in this relationship may be imparted by changes in phytoplankton CO_2 demand. The resulting standard error of the estimate of [CO_2 (aq)] (when $\delta^{13}C$ is specified) is <±2.0 μM, or an ocean/atmospheric pCO_2 estimation error that averages about 50 μatms when sea-surface temperature and plankton $\delta^{13}C$ are specified. Within this error of estimation there is relatively little difference among various proposed linear, logarithmic, and inverse models when fitted to the modern-ocean data set. When applied to the recent sedimentary record, such models predict that an approximate 80 μatms increase in atmospheric CO_2 during the last glacial/interglacial transition should result in a 2-3‰ decrease in plankton-derived sedimentary organic $\delta^{13}C$. Changes of about this magnitude are evident in several down-core profiles of organic $\delta^{13}C$ from contrasting regions. The analysis of phytoplankton-specific sedimentary organic compounds may improve paleo [CO_2 (aq)] and pCO_2 estimations once the empirical relationship between marine biomarker $\delta^{13}C$ and CO_2 concentration has been established. Further research is needed to better identify the usefulness and limitations of sedimentary organic $\delta^{13}C$ measurements in reconstructing past ocean and atmospheric CO_2 levels.

ODP SITE 851 - EASTERN EQUATORIAL PACIFIC ISOTOPIC RECORDS OF SURFACE CIRCULATION CHANGES

A.C. Ravelo (Marine Sciences, Univ. of California, Santa Cruz, USA) and N.J. Shackleton

One main objective of ODP Leg 118 is to investigate mechanisms of climate change in the eastern equatorial Pacific. As part of this effort, wind-driven surface water circulation can be reconstructed as a way of verifying observations of wind-field changes, and as a way of understanding the atmosphere-ocean interactions today and in the past when boundary conditions were different. This study of Site 851 is focused on reconstructing the upper ocean vertical temperature and nutrient gradients for the purposes of comparison to tropical and extra-tropical forcing functions.

ODP Site 851 is located at the northern edge of the South Equatorial Current in the Pacific Ocean (3°N, 115°W). Carbon and oxygen isotopes of *G. sacculifer*, a surface-dwelling species, and *G. tumida* and *N. dutertrei*, two sub-surface dwelling species, were measured in order to reconstruct the past vertical temperature and nutrient gradients in the photic zone (approximately the upper 100 m of the water column) over the last 3 Ma. As in previous studies, there is an overall trend in oxygen isotopes towards heavier values and higher amplitude glacial-interglaciation variations after the onset of northern hemisphere glaciation. On the other hand, carbon isotopes decrease and amplitudes of variation do not change. Carbon isotope values suggest that surface waters are more nutrient depleted during interglacials. During some parts of the record lower GRAPE values accompany the heavy carbon values indicating enhanced interglacial productivity by silicious plankton. However, much of the isotopic record does not co-vary with the GRAPE record. The carbon isotopic gradient decreases in interglacials due to the surface waters being more nutrient depleted while intermediate waters are more nutrient enriched. The oxygen isotope data suggest a more depressed thermocline during the glacials. At the location of Site 851 it is probable that this can be interpreted as increased surface winds during glacial periods.

ABUNDANCE OF TITHONIAN-BERRIASIAN TINTINNIDS IN WESTERN CARPATHIANS AND LIMITS OF THEIR DISTRIBUTION

D. Reháková (Geological Institute, Slovak Academy of Sciences, Bratislava, CSFR) and J. Michalík

Tintinnids became an important constituent of the planktic associations during Middle Tithonian. Small chitinnoidellas occur in the *Saccocoma* and *Globochaete* microfacies of the *Dobeni* Subzone. Later, they disappeared: only reduced association of Lower Tithonian planktic organisms characterize the "barren interval" between the *Dobeni* and *Boneti* Subzones. Later, *Chitinoidella* appeared again. Greater tests of the *chitinoidellas* are dispersed in *Saccocoma, Globochaete, Cadosina* and *Colomisphaera* association in packstones. The *Chitinoidella* Zone is represented irregularly in the Western Carpathian section, being often poorly identifiable. It remains a question whether this anomality is caused by primary unequal distribution of microplankton in the Tethyan Seas, or if the *Chitinoidella* tests were dissolved (the statement on their chitine composition seems to be problematic). Similar conclusions are applicable in the *Praetintinnopsella* distribution, although the test ultra-structure of this form is different.

Late Tithonian *Crassicollaria* and *Calpionella* association occurs in different types of sediment (wackestones). The share of *saccocomas* and *globochaetes* decreased; *crassicollarians* form relatively abundant accumulations.

Tithonian/Berriasian boundary is indicated by an explosion in calpionellid abundance. Elongated forms of *Calpionella* were substituted by small spherical *C. Alpina* Lorenz tests. They co-occur with *globochaetes, cadosinids* and radiolarians, which controlled the microfacies type. The middle Berriasian sequence is characterized by the presence of *Remaniella*, the upper one by *Calpionella elliptica* Cadisch. Decrease in calpionellid abundance started in the top Berriasian/early Valanginian *Calpionellopsis* Zone. Gradual decline of the calpionellid plankton continued till late Hauterivian, when the calpionellides were substituted by planktonic foraminifers.

The interpretation of sudden changes of tintinnid abundance and of their time and spatial distribution depends on the taxonomical concepts of this group. It is desirable to support and refine its taxonomy by the test ultra-structure study with the use of SEM. Provisional results of this study seem to be positive.

THE LAPTEV SEA POLYNYA AS SEDIMENT SOURCE FOR THE TRANSPOLAR DRIFT?

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Suspension freezing, the principal sea-ice, sediment-entrainment mechanism, requires shallow, open water or thin ice, wind, and low temperatures. Under these conditions, frazil and anchor ice forms, and then floats sediments to the surface. The discovery of an 1,800-km-long, recurring polynya in the Laptev Sea, already well known to the Russians, initially was thought to answer the question of sediment sources for Arctic sea ice.

The polynya borders the edge of the fast ice, which in early winter lies inshore at 10 m water depth, but by January extends to 20-30 m depth, over 200 km from land. The configuration of the inner edge of the sinuous polynya is controlled by bathymetry. Covered by nilas to grey ice (<15cm), its width from January through April typically is 15 km, but fluctuates with changing wind regime. Wind-parallel streaks of frazil extend to the fast ice edge, which lacks compressional ridges. All indications, therefore, are that the Laptev Sea remains an area of ice divergence and high ice production- and export rates throughout winter. The polynya, therefore, is indeed important for the Arctic Ocean's ice budget and its intermediate and deep water.

The new ice advected offshore, constituting one of the tails for the Transpolar Drift, appears to contain little sediment during April. This fact may be due to fresh-water discharge of the Lena River, causing stable water stratification, and preventing super-cooled water and suspension freezing to reach the bottom at 20-30 m. However, Zakharov (1966) stated that, even in the southern part of the Laptev Sea, the 22 m depth of convection is quite sufficient to reach the bottom, and that this promotes aeration of bottom waters and also benthic life. These contradictions: lack of sediment inclusions and the apparently sufficient convection depth in the polynya, call for specific winter studies of entrainment processes to be made. Early winter, before the fast-ice covers the extensive shallows and when stormy weather and water turbulence prevail, is thought to provide optimum conditions for sediment incorporation into this tail of the Transpolar Drift.

Zakharov, V.F., 1966, The role of flaw leads off the edge of fast ice in the hydrological and ice regime of the Laptev Sea: Academy of Sciences of the USSR, v.6, n.1. p.815-821.

MODELING UNCONFORMITY-BOUND SEQUENCES AT PASSIVE CONTINENTAL MARGINS: IMPLICATIONS FOR THE MEASUREMENT OF CENOZOIC SEA-LEVEL CHANGE

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It is now widely recognized that the stratal geometry and arrangement of sedimentary facies at passive continental margins are a result of a complex interplay between subsidence, sediment supply and eustasy. This interplay involves both positive and negative feedback and consequently both leads and lags are developed between the sedimentary response and any driving perturbation. This means that even if eustasy is assumed to dominate the stratigraphic record for the Oligocene to Recent, neither the timing nor the amplitude of eustatic change can be directly inferred from the stratigraphic record without making assumptions about tectonic subsidence, sediment supply, isostasy and compaction. Forward models provide key insights about the sensitivity of sedimentation to variations in key parameters, and therefore clues about how the stratigraphic record ought to be interpreted.

We have produced simple, physically-based models that illustrate the importance of the sediment load and compaction on the development and partitioning of accommodation across a passive margin. We conclude that a sequence boundary may be diachronous and may pass laterally into correlative conformities of different age. Variations in the rate of subsidence and sediment supply and the existence of a break in depositional slope influence the partitioning of sequences into systems tracts.

The complexities of measuring sea-level change are well illustrated in the vicinity of the mid-Atlantic Transect, New Jersey margin. We have backstripped an interpreted seismic section using a two-dimensional routine that includes compaction and isostasy. Reconstruction of the margin at intervals throughout the Cenozoic shows an evolution of sequence geometry from ramp to a profile with a distinct shelf-slope break. Along the New Jersey margin, observations and models suggest that Oligocene to Recent sequences are dominated by lowstands owing to the low subsidence rate, relatively rapid glacial-eustatic sea-level change and the existence of a break-in-slope. Current research, including new seismic data, $\delta^{18}O$ records and proposed ODP drilling, will provide a test of our modeling studies.

LATE PLEISTOCENE SEA-LEVEL AND CLIMATE CHANGE BASED ON HIGH-PRECISION MASS-SPECTROMETRIC ^{230}Th AGES OF SPELEOTHEMS FROM THE BAHAMAS

D. A. Richards (Univ. of Bristol, U.K.), P.L. Smart, and R.L. Edwards

Submerged speleothems (secondary calcite cave deposits) from the tectonically stable Bahamas provide a comprehensive and datable record of late Pleistocene sea-level and climatic fluctuations. Continuous growth of samples is punctuated by hiatuses which represent periods of either, inundation of caves by rising sea levels or regional paleoclimatic control.

ass-spectrometric facilities at the University of Minnesota have enabled high-precision ^{230}Th dating of sub-samples (<200 mg and < 1mm) along the axes of speleothem growth. Results on a flowstone sequence from Grand Bahama, 20 m below present sea level, have constrained the age of initiation of growth after the sea level regressions associated with the isotope stage boundaries 5/4, 7/6 and 9/8(?) to 79 ± 2 ka , 190 ± 5 ka and 304 ± 8 ka, respectively (all ages 2σ). Ages along growth phases indicate the rate of speleothem deposition during each glacial period. This is considered to be primarily linked to effective recharge in this region.

Near-synchronous cessation of growth during the last glacial period, for samples in the northern Bahamas (to depths of 58m), occurs at ~16 ka, ~6 kyr prior to the expected deglacial sea-level rise. This may be a regional climatic effect as arid conditions prevailed with the onset of cold Laurentide Ice Sheet meltwater flow into the Gulf of Mexico. The effect of past and present climatic control on growth of subaerial samples collected from other islands of the Bahamas and the Turks and Caicos Islands further to the south will be discussed. (Present day rainfall totals vary along this north-south profile from 1500 to 600 mm a^{-1}.)

The speleothem results reported provide both high-precision chronological 'markers' for the Late Pleistocene as well as a record of key paleoclimatic events.

CORRELATION OF HIGH-RESOLUTION ECHOSOUNDING AND SEDIMENT PHYSICAL PROPERTY MEASUREMENTS ON THE CEARA RISE

M. Richter (Universität Bremen, Germany) and M. Breitzke

During RV METEOR cruise M16/2 in spring 1991 the northeastern flank of the Ceará Rise in the western equatorial Atlantic was surveyed with continuous high-resolution digital echosounding profiles using the PARASOUND system. In addition, the upper about ten meters of the sediment column were sampled with a series of gravity cores along two transects.

High-resolution P-wave velocity, wet bulk density and magnetic susceptibility measurements were performed on all cores yielding a distinct positive correlation between P-wave velocity and wet bulk density logs and a negative correlation of these two parameters with the magnetic susceptibility.

The P-wave velocity and wet bulk density measurements result in acoustic impedance logs which are used as input data for the computation of synthetic seismograms at each core station. Their comparison with the recorded digital echograms provide a means to link the lithological variations with strong amplitude reflected wave groups. The continuous PARASOUND sediment echosounding profiles allow to image the lateral extension and variability of these reflection patterns from the top of the Ceará Rise to its northeastern foot along a SW-NE striking line. Based on the oxygen isotope and magnetostratigraphy results of Nowaczyk et al. (Poster presented at this conference) and using the negative correlation of the magnetic susceptibility and the acoustic impedance logs individual reflection horizons were dated.

ATOLL DRILLING IN THE NORTHWEST PACIFIC: FIRST RESULTS OF ODP LEG 143

U. Röhl (Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, Gemany) and the Shipboard Scientific Party

Numerous seamounts of Cretaceous age, many of which are now flat-topped guyots, occur in the Western Pacific in water depths of 1 to 2 km. Most of these guyots are capped by pelagic and shallow-water limestones overlying volcanic edifices. ODP Leg 143 (March-May, 1992) drilled four sites in two guyots of the Mid Pacific Mountains, plus a basinal site in the Marshall Islands region.

The vertical facies succession in Site 865 (Allison Guyot) and the ODP deepest single record Hole 866 ("Huevo" Guyot, 1735 m) traces the evolution of a carbonate atoll from its early history to final drowning. The Barremian to Albian shallow-water sequences are ideal to study relative changes in sea level by analyzing facies and diagenetic features. All kind of subtidal, intertidal and supratidal minor-scale rhythms and cycles are documented, meteoric-phreatic to meteoric-vadose alterations of sediments are abundant. Although the carbonate productivity and sedimentation kept pace with relatively rising sea level, the morphology of the Albian carbonate platform at "Huevo" Guyot was very different from that of Neogene atolls: Instead of a wave- resistant reef at sea level with steep seaward flanks surrounding a deeper lagoon, the Early Cretaceous oceanic platform had a submerged platform edge, calcareous sand bars inward from the platform rim partly protected the very shallow lagoon. Rudists and coral communities thrived on the uppermost slope of the ramp.

Detailed investigations are underway to separate the effects of local or regional tectonic subsidence history of the seamounts and of global fluctuations of sea level. The correlations between sites of different guyots, drilled on this Leg, and comparisons with other Cretaceous sequences are very important.

PALAEOCEANOGRAPHIC IMPLICATIONS OF ORGANIC MOLECULAR STRATIGRAPHY DATA: A COMBINED FIELD/ANALYTICAL ASSESSMENT STUDY

A. Rosell (School of Chemistry, Univ. of Bristol, UK), J.F.Carter, G.Eglinton, A.Castellnou, and J.Grimalt

Molecular stratigraphy derived from the analysis of organic compounds in marine sediments can provide palaeo-information on sea-surface temperature, primary productivity and/or wind stress. However, this information may be obscured by relevant aspects to sediment diagenesis such as total organic content (TOC), different sediment matrices and complex chemical composition. These aspects influence the stratigraphic distribution of trace lipid compounds such as alkenones and alkenoates, pigments, sterols, n-alcohols or n-alkanes, which constitute the group of target organic species in stratigraphic studies.

Among them, the compounds most often studied for stratigraphic purposes are the C_{37} alkenones. These, together with C_{38}, C_{39}, and C_{40} alkenones and C_{36} methyl and ethyl alkenoates, are biosynthesized by the Prymnesiophyte algae. The U^{k}_{37} index, derived from C_{37} alkenone abundances, provides information on the temperature of the euphotic zone where these compounds are synthesized and has been used to reconstruct palaeo sea-surface temperatures.

To date, most of the samples studied are from low latitudes and upwelling areas. The extension of this index to high and mid-latitude cores involves some difficulties that have to be overcome, such as more complicated sample matrices, low compound abundances, and validation of the U^{k}_{37} calibration with low sea-surface temperatures.

This requires a systematic field study encompassing high and low latitude sediments as well as a considerable increase in analytical performance. We report on the use of combined gas chromatography-mass spectrometry with ammonia chemical ionisation (GC-CIMS) as an alternative to gas chromatography for the analysis of alkenones and alkenoates in stratigraphic studies of marine sediment cores. The CIMS method gives high selectivity for compounds of a given molecular weight containing oxygen, thus eliminating many of the chemical interference in the GC analysis. In addition the sensitivity, reproducibility and speed of the method are also enhanced.

MOLECULAR STRATIGRAPHY OF MID- AND HIGH-LATITUDE NORTHEASTERN ATLANTIC CORES

A. Rosell (School of Chemistry, Univ. of Bristol, UK), P.Merryweather, G.Read, G.Eglinton, J.Villanueva, and J.Grimalt

Organic molecular stratigraphy is becoming an increasingly important tool for the reconstruction of palaeonvironments. Sea Surface Temperature (SST) information can be derived from the relative abundances of a group of organic compounds (long chain alkenones and alkenoates) biosynthesized by the *Prymnesiophyte* algae. The U^{k}_{37} index, derived from the C_{37} alkenones has been found to be related to the temperature of the euphotic zone at the time these compounds were biosynthesized.

To date, molecular stratigraphy studies have been confined to low latitudes and upwelling areas. U^{k}_{37} stratigraphy has seldom been undertaken in cores from mid or high latitudes. This poses some analytical problems (e.g. sensitivity, complex sample matrices) and may force the introduction of a new palaeothermometer index (Integrated Production Temperature, IPT, using alkenones and alkenoates abundances) in order to get more accurate absolute SST, as reported recently by Maureen Conte and co-workers from Bristol.

The cores Meteor-23259 (Norwegian Sea; 72°01'N, 9°16'E), Meteor-23260 (Norwegian Sea; 72°09'N, 11°27'E), Meteor-17049-6 (Maury Channel; 55°16'N, 26°44'W), BOFS 5K (East Thulean Rise; 50°41'N, 21°52'W) have been analyzed at 1cm intervals, extending back to 30,000 years, for SST (U^{k}_{37}-IPT). Total alkenone-alkenoate and pigment abundances analysis have also been carried out. These provide information on primary productivity and water column conditions. Results give an indication of the effect of the Younger Dryas event in SST values and provide more arguments for the discussion of the conveyor belt hypothesis and heat transport to the Norwegian Sea.

A DYNAMIC MODEL OF CARBON CYCLING IN UPWELLING CELLS ALONG COASTAL MARGINS

R.M. Ross (Geological-Paleontological Institute, Christian-Albrechts Univ., Kiel, Germany), M. Sarnthein, and K. Winn

Ocean carbon models have previously concentrated upon open ocean processes, in spite of empirical evidence that at least half of planktonic carbon sequestration takes place along the more dynamic and productive continental margins. A two-dimensional dynamic model of wind-driven coastal circulation (by E. Maier-Reimer, MPI, Hamburg) and C cycling has been created to estimate the effect of coastal upwelling upon organic C burial and atmospheric CO_2 since the LGM. The model uses primarily parameters and tracer fields that can be estimated from paleoproxy data. The model was first applied to modern and Quaternary conditions off the coast of northwest Africa, and is now being applied to other upwelling centers off southwest Africa, Peru, Panama, and the western U.S.

In this model, tracers include PO_4, POM, ΣCO_2, and carbonate alkalinity. Modeled production is a function of PO_4, POM, and light; organic flux sinks at a uniform rate, is remineralized, and readvected. Carbonate and opal sedimentation are functions of productivity, and siliciclastic sedimentation depends on wind-speed, distance from shore, and regional aridity. Organic C burial is a semi-empirical function of productivity, depth, and total sedimentation, derived from Eastern Atlantic core data. Sediment transport is proportional to the bottom gradient. The model runs are based on an annually stationary field (with varying degrees of seasonality) derived from several years of model integration (Δt = 3h). Within 250 km of shore, tracer fields agree well with empirical records from Meteor and JOINT-1 cruises off northwest Africa.

The model confirms that several factors operate in the same direction to create higher C_{org} burial during glacials: (1) sea level drops alone increase intensity of upwelling to the sea surface; (2) primary productivity and C_{org} burial along the coast increase non-linearly with increases in wind speed (and consequent advection); (3) this non-linearity is magnified by amplified seasonality; (4) increased wind speeds enhance C_{org} burial off arid areas such as NW Africa through increased eolian sedimentation. Regional variations in topography and climate modify the relative contributions of these factors to local changes in coastal carbon budgets.

170,000 YEAR SEA-SURFACE TEMPERATURE (SST) AND ORGANIC CARBON RECORD FROM THE NORTHERN INDIAN OCEAN

F. Rostek (Lab de Geologie due Quaternaire, CNRS, Marseille, France), G. Ruhland, F.C. Bassinot, P.J. Müller, E. Bard, L. Labeyrie, and Y. Lancelot

We have measured the unsaturation ratio of C_{37} alkenones and the organic carbon content for the first 10 meters of core MD900963 (05°04' N / 73°53' E, water depth 2450 m). This core was recovered east of Maldives islands during the SEYMAMA expedition which took place in 1990 in the Equatorial Indian Ocean. The data enable us to reconstruct SST and productivity records for the last 170,000 years, which can then be compared with the $\delta^{18}O$ and carbonate curves.

The SST record from this site exhibits rather small variations between 25 and 28°C. Low SST's are observed within oxygen isotope stages 4 and 3 with a broad minimum centered within stage 3. High SST values near 27 - 28°C characterize oxygen isotope stage 5. The glacial episodes 5.2 and 5.4 are not clearly present in the SST reconstruction. For stage 6, SST's are about 1.5°C higher than those obtained for the broad minimum in stage 3. The SST variations are also correlated with the carbonate record which varies between 30 and 80%.

The organic carbon content changes between 0.2 and 0.9% and is strongly correlated with the $\delta^{18}O$ record (i.e., highest values associated with glacial $\delta^{18}O$ maxima and lowest values with interglacial maxima).

By taking into account the $\delta^{18}O$ variations, we also calculated mass accumulation rate of organic matter. These results will be discussed and compared with previous works dealing with the monsoon variations during the last glacial cycle.

CENOZOIC PLATEAU UPLIFT AND PALEOCEANOGRAPHY

W.F. Ruddiman (Dept. of Environmental Sciences, Univ. of Virginia, Charlottesville, USA)

Plateau uplift on a very large scale has occurred in Tibetan Asia (last 40 Myr); the American West (last 70 My), East Africa (last 30 My), and the Bolivian Altiplano of South America (last 30 My). The extent of high plateau topography (predominantly Tibet) may be greater than at any time since the Paleozoic. Model sensitivity tests indicate numerous potential effects of uplift on ocean circulation, with most of these effects susceptible to testing in the geologic record.

Model results indicate that high plateaus increase seasonal exchanges of atmospheric mass between continents and oceans, mainly in the Northern hemisphere, and this should have diverse effects on oceanic circulation. Summer heating of Tibet drives a large monsoonal flow of air into India and strengthens upwelling near Arabia. As compensation for rising motion over Tibet and other plateaus, subsidence of dry air into the summer subtropical highs over North Atlantic and North Pacific intensifies. In winter, the sense of air-sea exchange reverses, with increased subsidence over the cold plateaus and accompanying intensification of rising motion in the Aleutian Low and along the east coast of North America.

Dynamic effects of the plateaus include repositioning and intensification of the Rossby waves and lower westerlies, including increased south-to-north flow in the eastern North Atlantic. Uplift also alters the global runoff budget via monsoonal flow and orographic/rainshadow effects. Other likely effects of the plateaus include increased chemical erosion, which would draw down atmospheric CO_2 and lead to resultant effects on sea-ice extent, high-latitude, mixed-layer temperatures, and (presumably) deep-water formation.

LATE QUATERNARY VARIABILITY OF ALKENONE SEA SURFACE TEMPERATURES IN THE EASTERN ANGOLA BASIN

G. Ruhland (Univ. of Bremen, Germany), P.J. Müller, and R. Schneider

Records of past sea surface temperatures (SSTs) derived from the alkenone U^{k}_{37} index, spanning the last 200,000 years, are presented for the eastern Angola Basin and the Walvis Ridge. Comparison of SST estimates from surface sediments between 5° and 20°S with modern SST data revealed that the alkenone temperatures represent annual mean values with a slight tendency to warm season temperatures at the Walvis Ridge. The strong SST gradient of 4° to 5°C which characterizes the thermal Angola Benguela Front (ABF) at about 15°S is clearly reflected in the results from surface sediments.

Alkenone temperatures for the warm climatic maxima during isotopic stages 1.1 and 5.5 were 1 to 2° C higher than late Holocene values. All records show glacial to interglacial SST differences of about 4°C, which is comparable to the difference estimated by CLIMAP (1981, 1984) for the eastern Guinea Basin. Time series analyses revealed that the SST records contain a significant 23,000 year periodicity. The phase relationships show that changes of SST in the eastern Angola Basin lag those on the Walvis Ridge and in the Equatorial Atlantic by approximately 2,000 years, and that they are nearly in phase with SST variations reported for the eastern Cape Basin (IMBRIE et al.1990). This points to a time lag between the northward cold water advection of the coastal and oceanic branches of the Benguela Current.

Comparison of the SST records from north and south of the ABF shows that the present temperature gradient also prevailed during the last 200,000 years. This suggests that the position of this oceanic frontal system remained fairly stationary between 12° and 20°S (the limits of our cores) during the last two glacial-interglacial cycles. Moreover, the surface cyclonic circulation of the eastern equatorial South Atlantic, which at present results in the convergence of warm tropical waters and cold southern upwelled waters at the ABF, probably also prevailed seasonally during glacials.

Both observations - the phase relationships of the 23,000 year periodicity in alkenone-based SST variations, and the glacial cyclonic surface circulation in the eastern Angola Basin - suggest that the intensified advection of cold water in glacial periods took place through the western Angola Basin rather than along the African coast as has been suggested by other studies.

URANIUM IN FORAMINIFERAL CALCITE AS A RECORDER OF CHANGES IN SEA-WATER URANIUM CONCENTRATION

A.D. Russell (School of Oceanography, Univ. of Washington, Seattle, USA), S. Emerson, B. Nelson, J. Erez, and A. Mix

A record of the extent of deep-ocean anoxia would be valuable for constraining changes in ocean-mixing and biological productivity in the past. Variations in sea-water uranium concentration over time may provide such a constraint, since removal of uranium into sediments overlain by anoxic or low-oxygen bottom waters is an important sink in the uranium mass balance of the ocean. We report the development of uranium in foraminiferal calcite as a recorder of changes in sea-water uranium concentration.

Culture experiments in which live benthic foraminifer (*A. lobifera*) were raised in solutions spiked with varying amounts of uranium show that U:Ca in cleaned calcite tests is proportional to U:Ca in solution, with an apparent distribution co-efficient between calcite and sea-water of 0.01; results of similar experiments recently conducted with planktic species *G. calida* will be reported at the conference.

Downcore U:Ca in *N. dutertrei* from an equatorial Pacific core indicates no change over the last 25 kyr within an overall scatter of 8%, while U:Ca in glacial *G. tumida* are on average 14% lower than in Holocene specimens. However, U:Ca in these species decreases downslope by a factor of two in Ontong Java Plateau core tops ranging in depth from 1614 to 4425 m, suggesting a dissolution artifact caused by inhomogeneous distribution of uranium in the tests. We are presently searching among planktic foraminifer for species in which uranium is homogeneously distributed with the test calcite, so that dissolution does not alter the measure U:Ca. Results will be pesented at the conference.

ADVECTIVE TRANSPORT OF PARTICLES IN THE ANTARCTIC CIRCUMPOLAR CURRENT, DEDUCED FROM DISCREPANCY BETWEEN TRAP FLUX AND SEDIMENT ACCUMULATION OF ^{210}Pb

M.M. Rutgers van der Loeff (Alfred-Wegener Institute, Bremerhaven, Germany)

In the opal accumulation belt in the Southern Ocean, the long-lived natural radionuclides ^{230}Th and ^{231}Pa are deposited in excess of their production rates in the overlying water column. The accumulation rate of ^{210}Pb (22.3 y half-life) is similarly enhanced compared to sediments north and south of the high-accumulation zone. This has been interpreted as indication of excess scavenging related to high productivity ^{230}Th and correspondingly high particle fluxes at the Antarctic Polar Front. This hypothesis was put into doubt by the observation that ^{230}Th and ^{231}Pa are not depleted in the water column of the Antarctic Circumpolar Current (ACC).

In a 1-year sediment trap deployment at the average position of the Polar Front (50° 07.6'S, 5° 50.0'E, 3785 m water depth, Wefer and Fischer, unpublished results) the flux of excess ^{210}Pb was measured at 614 and 3200m depth. At 3200m, the annual flux of excess ^{210}Pb would maintain a steady-state sediment inventory of only 2.0 dpm/cm^2, far below the range of inventories we observed in the high-accumulation zone (4.0-35.1, average 20 dpm/cm^2).

This discrepancy is too large to be explained by interannual variability in the vertical flux, incomplete trap collection efficiency, or a bias in the selection of coring locations. Nor is it likely that scavenging in the lower 500m of the water column and at the sediment surface could be responsible for the discrepancy. These flux data of ^{210}Pb support the indication based on the lack of depletion of ^{230}Th and ^{231}Pa in the water column, that an important part of the activity is derived from lateral advection rather than from excess scavenging. This would imply that the sedimentary record in the high-accumulation zone is seriously influenced by advective transport in the ACC.

PARTICULAR FLUX UNDER MELTING SEA ICE IN EAST GREENLAND CURRENT

M. Saarso (Tallinn, Estonia)

Two sediment trap experiments were carried out in June 1990 during PRV POLARSTERN cruise ARK VII/1 in the area of Vesterisbank Seamount . We deployed arrays with HYDRO-BIOS sediment traps at depths of 20, 30, 40, 60, 80, 100m from drifting ice floes for 7 and 9 hours.

The measured particulate flux values range between 13 and 97 mg/m/day. The number of microscopically detected lithogenic particles in the size range of 4 µm is 2 to 10 particles per sample. The results of both experiments show an analogical flux profile with a well-defined maximum at 40 to 60m and a decrease between 20 and 30m.

The small particulate flux values and extremely low lithogenic flux are due to relatively slow melting of very little sediment containing ice. The vertical flux profile is explained with thermohaline stratification of water column

SPOREN AND POLLEN COMPOSITION OF EOLIAN SUSPENSION OVER THE OCEAN AS AN INDICATOR OF CLIMATIC ZONALITY

S. Safarova (P.P. Shirshov Institute of Oceanology, Academy of Sciences, Moscow, Russia)

Vast materials concerning the spore, pollen and mineral composition of eolian suspension over the oceans, were collected during numerous oceanographic expeditions. The research was based on general quantitative distribution of the suspensia, its granulometic composition and palynological characteristics. The distance of air samples from the points of on-shore meteorological conditions, wind directions, and velocity and air humidity were taken into consideration. As a result, general pollen and spore compositions in the air suspension over the oceans were estimated, and also peculiarities were found of the process of formation of the present pollen and spore complexes, depending on the vegetation type of the surrounding land, the shore distance, etc. It is demonstrated that the spreading range of certain spore and pollen specimens is defined by morphological qualities of pollen granules. The regularity of pollen and spore sedimentation in the surface layer of bottom sediments was also discovered. The definition of the composition of spore and pollen complexes depends on the genetic types of deposits. As a result, we conclude that the distribution of pollen and spore eolian suspension over the ocean is controlled by the circumcontinental and climatic zonalities.

As an example, we present the data on the composition of spore-pollen complexes from the eolian suspension above the Bering Sea and from the bottom sediments. This research serves as an actualistic model for the reconstruction of paleoclimate in the ocean. Maps of the climatic zones of the Pacific Oceans and its continental frame were constructed together with *N. Blyum* for several time intervals within the Neogene - Quaternary epoch.

GEOTHERMAL HEAT - A TRIGGER OF OCEAN CIRCULATION

S. Sakai (Dept. of Earth Sciences, Kyoto Univ., Japan) and T. Kimoto

As Stommel (1961) pointed out, the ocean circulation can have two stable circulation modes even when the ocean is considered as a one-cell convection, driven by heat and salinity differences. One circulation is sustained by salinity flux due to precipitation and evaporation. It has relatively weak circulation in the opposite direction of the present mode but is stable to changes in the parameters. The other one is sustained by heat flux and has strong circulation in the same direction of the present mode. Its stability is sensitive to changes in the parameters. This is due to longer restoring time scales for salinity than heat.

Recent numerical experiments (Manabe and Stouffer, 1988) found difficulties in simulating present thermohaline circulation of the ocean using the so-called "mixed condition". This condition gives surface temperature restored to observed value in a few months, while salinity flux is fixed at the surface. This is equivalent to infinite restoring time scale for salinity. Although this condition seems to be reasonable, they had to largely modify salinity condition from the observed value to obtain realistic circulation, otherwise they obtained a circulation of the glacial age.

Their results, however, also showed that Stommel's simple model contains the essential process of the circulation, because the results of the numerical experiments are qualitatively consistent with Stommel's regardless of the difference in their complexity. Both models show that once salinity-sustained circulation has been achieved, it is very difficult to jump to heat-sustained circulation corresponding to the present circulation of North Atlantic.

We have modified Stommel's model considering geothermal heat flux. This model shows that this jump can be done by thermohaline catastrophe at high latitude due to the accumulation of geothermal heat. This flux is very small, but it is not negligible when the ocean is inactive, especially in a semi-closed basin like the Arctic Ocean, where no deep-water formation is expected in a glacial period. This model also shows self-sustained oscillation of several ten thousand years corresponding to the glacial cycle.

LIVING COCCOLITHOPHORE COMMUNITIES IN THE NORWEGIAN-GREENLAND SEA AND THEIR DISTRIBUTION IN SURFACE SEDIMENTS

C. Samtleben (Geological-Paleontological Institute, Christian-Albrechts Univ., Kiel, Germany), K.-H. Baumann, and A. Schröder

The distribution of coccoliths in surface sediments has been examined in samples from the entire Norwegian-Greenland Sea.

Living coccolithophore communities in the Norwegian-Greenland Sea can be classified in three regional groups tracing the corresponding surface water masses: (1) an Atlantic group, (2) an Atlantic-Arctic group, and (3) an Arctic group. These assemblages are decomposed and altered during descent in the water column by destruction and solution of delicate heterococcoliths and all holococcoliths leaving only few species.

Samples from surface sediments contain significantly less coccolithophorid species than are included in living communities in the same area. But based on their concentration and diversity and the ratio changes between *Emiliania huxleyi* and *Coccolithus pelagicus* it has been possible to establish biogeographic zones. Thus, the coccolith distribution in surface sediments in the Norwegian Sea seems to give a good description of the various locations of various water masses in the area.

DIATOMS IN SEDIMENT TRAPS FROM THE GULF OF CALIFORNIA

C. Sancetta (National Science Foundation, Washington, USA), R. Thunell, L. Keigwin, and D. Murray

We have collected one and one-half years of biweekly, sediment-trap samples at two sites in the Gulf of California. Although both moorings experienced incomplete collection, we have been able to resolve the primary features of the annual flux. The annual maximum in diatom flux occurred in late fall to winter (November - January); spring through fall fluxes were roughly equal, and a factor of 2-3 below that of winter. The winter assemblage was the most diverse and included both coastal and warm-water pelagic forms, implying enhanced transport of Pacific waters into the Gulf. We speculate that a mechanism other than upwelling was responsible, since winds are not particularly favorable for upwelling during this time. Possibilities include mesoscale eddies, and vertical migration of the nutricline related to internal waves. The spring assemblage was characterized by typical coastal-upwelling taxa such as *Skeletonema costatum* and *Chaetoceros radicans*. The relatively low fluxes at depth during this season may reflect high grazing and recycling in the upper water column, rather than lower production. Summer and early fall samples included taxa typical of subtropical gyres, implying that production was fueled by recycled nutrients and the mixed zone was shallow.

GLACIAL TO INTERGLACIAL VARIATIONS IN EAST ATLANTIC DEEP-WATER CIRCULATION

M. Sarnthein (Geological-Paleontological Institute, Kiel, Germany), K. Winn, J.-C. Duplessy , L. Labeyrie, and H. Erlenkeuser

Based on more than 80 carbon isotope records, eight time slices were reconstructed for the distribution of East Atlantic deep-water masses over the last 30,000 years. The reconstructions show that deep-water formation in the northern North Atlantic was similar to today at the end of $\delta^{18}O$ event 3.1. During the Last Glacial Maximum (LGM) a reduced formation persisted, but the source region of deep water shifted from the Norwegian-Greenland Sea during late stage 3 to areas south of Iceland, and the nutrient content of the deep water increased markedly near the Azores by an admixture of AABW from below. About 13,600 ^{14}C yr ago, when meltwater spread far over the northern North Atlantic, the Atlantic below 2000 m became almost stagnant during Termination Ia. Near 13,000 yr and especially, about 12,500 yr ago, deep-water formation quickly recovered. During the Younger Dryas it reached an extent only little smaller than in the Holocene. Later, another short-term breakdown in deep-water formation occurred near 10,000-9,600 yr B.P., along with the second major meltwater incursion. After 9,000 yr ago, the distribution of deep-water masses was similar to today and varied little. During the complete time span studied, the outflow of Mediterranean water varied independently of the variations in deep-water circulation.

THE MELTWATER WORLD

M. Sarnthein (Geological-Paleontological Institute, Christian-Albrechts Univ., Kiel, Germany), M.S. Weinelt, H. Erlenkeuser, and E. Jansen

$\delta^{18}O$ records from the Norwegian Greenland Seas contain a long series of meltwater events which are common accidents to all climatic stages during which major ice sheets covered parts of the eastern margin of this sea. Over the last 80,000 years we observed preglacial meltwater pulses near about 80, 41, 37 ky, a double spike at 30.8 and 33.7 ky BP and at 26 ky BP. A single, peak glacial meltwater episode occurred at 18 ky BP; deglacial episodes were found at 55, 13.6, 12.3 kyrs and possibly near 8 ky BP.

During preglacial stage 3 and the advanced deglaciation, negative $\delta^{18}O$ deviations linked to spreading icebergs and meltwater plumes follow a largely counter-clockwise pattern of surface circulation, as in the Holocene. During the Last Glacial Maximum (18 ky BP) and the earliest deglacial state (13.6 ky BP) the meltwater anomalies start at the Barents Shelf and the distribution pattern suggests a clockwise surface-water circulation in the Norwegian-Greenland Sea and the North Atlantic, and a corresponding marked cooling of adjacent northwestern Europe.

Most meltwater pulses were paralleled by short episodes of low benthic $\delta^{13}C$ in the North Atlantic, indicating a reduction or elimination in NADW formation and of the salinity conveyor belt. This reduction induced short-term climatic setbacks when the budget of solar insolation at 65°N was positive. After the events at 26.1 and about 80 ky BP when the insolation reached a minimum, major glaciations started.

THE BENTHONIC FORAMINIFERA TEMPERATURE EXPERIMENT (BFTREX): AN IN SITU APPROACH FOR DETECTING GLOBAL WARMING IMPACT

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The BFTREX was designed to evaluate the response of near-shore benthic foraminifera populations to a +4°C above ambient temperature increase of coastal bottom water. Eight 50 cm x 50 cm pans containing plastic vials filled with sterile sand serve as a substrate for colonizing species; the pans were placed at a 9 m deep location in Bedford Basin (Halifax Harbour). Four of the pans were heated so that the upper two cm of the sand was held at +4°C using a sensing circuit that tested the temperature every six seconds and adjusted the heating interval (duty cycle) every two hours. The experiment was operational from July 20,1990 to the end of February,1992 and was sampled seven times by SCUBA divers.

Densities of 14 living species from the top cm of sand were analyzed by three-way ANOVA's with the hypothesis for heat, time, pans and their interactions. As expected, all species had significant differences with time. The hypothesis for heated versus unheated sand was significant for six species, and five of these had higher densities in unheated sand. Three of the four arenaceous species tested had significant differences with respect to heat suggesting that this group is by far the most sensitive to temperature changes.

Preliminary evaluation of raw data suggests that colonization rates may be slightly higher for heated substrate in late autumn and for unheated substrate

during the summer. During the summer of 1991, total species colonization rates on heated substrate was three times lower than observed on unheated substrate. These observations suggest the possibility that some species in the living population may migrate to shallower or deeper water in order to remain within a preferred temperature range.

THE DIATOM RECORD FROM BENEATH THE WEST ANTARCTIC ICE SHEET AND THE GLOBAL PROXY PERSPECTIVE

R. P. Scherer (Byrd Polar Research Center, Ohio State Univ., Columbus, USA)

Recent glaciological evaluation and modeling of the marine-based West Antarctic Ice Sheet (WAIS) support the possibility that the WAIS may have disintegrated during one or more Pleistocene interglacial period. The magnitude of sea level and oxygen isotope variation during certain late Pleistocene interglacial periods is also consistent with the possibility of major retreat of the WAIS. Although oxygen isotopes from deep-sea sediments provide the best available proxy record for global ice volume (despite the ambiguities inherent in that record), the source of ice volume changes must be hypothesized. Futhermore, high frequency ice volume changes may not be adequately recorded in relatively low accumulation rate marine records.

Seismic reflection studies through the WAIS have revealed thick successions of strata wih seismic characteristics comparable to upper Tertiary marine sediments. Small samples of glacial diamictons from beneath the ice sheet have been collected via hot water drilled access holes. These sediments include mixed diatom assemblages of varying ages. Late Miocene diatoms dominate many samples, probably reflecting marine deposition in West Antarctic basins prior to development of a dominantly glacial phase in West Antarctica. In addition to Late Miocene diatoms, samples from Upstream B (1988/89) contain rare post-Miocene diatoms, many of which imply deposition in the West Antarctic interior during one or more Pleistocene deglaciation.

Age-diagnostic fossils in glacial sediments beneath ice sheets provide relatively coarse chronostratigraphic control, but they do contain direct evidence of regional deglaciation. Thus, sub-glacial till samples provide the evidence regarding the source of ice sheet variability seen in well dated proxy records. Combined, these independent data sets can provide a more comprehensive and less speculative interpretation of the history of past glacial minima in currently glaciated polar regions.

LATE QUATERNARY PALEOBIOGEOGRAPHY OF THE BENGUELA CURRENT, WALVIS RIDGE, AND THE SE ATLANTIC

H. Schmidt (University of Bremen, Germany) and G. Wefer

The Benguela Current, the eastern boundary current of the South Atlantic gyre, is divided into a northward-directed, cold, near-coastal upwelling flow and a northwest-to-westward flowing, warm, oceanic part. A major contributor to the Benguela Current is the South Atlantic current, and minor portions are introduced by the Agulhas Current from the Indian Ocean and subantarctic surface water. Surface waters in the Walvis Ridge area, which lies under the oceanic part of the current, are further influenced by cold, nutrient-rich water from coastal upwelling. The upwelling water is supplied by South Atlantic central water which, in turn, originates at the subtropical convergence by mixing of subtropical and subantarctic surface waters. It is incorporated into the oceanic part of the Benguela current by way of offshore transport perpendicular to the coast as so-called "filaments." Also, warm, subtropical surface water can reach the study area from the north, depending on the position of the Angola-Benguela Front.

The complex surface circulation pattern is clearly reflected in the sedimentary planktonic foraminiferal assemblages as a distinct E-W zonality. At the eastern end of the transect along the long axis of the Walvis Ridge (ca. 400 km off the coast of Namibia), the assemblages are dominated by *N. pachyderma* and *G. bulloides* contributing up to 60% and more. While the former species is characteristic of cool temperatures, the latter species is indicative of upwelling. Farther to the west, species like *G. truncatulinoides* and *G. ruber*, that are typical to warm and rather nutrient-depleted environments, gain importance. There is a sharp transition between these two regimes. It appears to be confined to the gap in the Walvis Ridge at about 7°E and has been relatively stable for the past 250 ky.

A prominent feature of the faunal records is the pulses of *N. pachyderma* (sinistrall) since Termination II. Since this species is abundant only in high latitudes, the spikes indicate the episodically strong influence of subantarctic surface water.

At about the same time, *G. hexagonus* disappears in Atlantic Ocean sediments and, since then, is found only in the Pacific and Indian Oceans. Also, distribution curves of several other species exhibit marked changes at the isotopic stages 6/5 boundary. these patterns are attributed to a decrease in addition of Agulhas surface water from the Indian Ocean, while an admixture of subantarctic surface and central waters increased.

TRACING THE LATE QUATERNARY INTERBASIN EXCHANGE IN THE BENGUELA CURRENT SYSTEM

H. Schmidt (University of Bremen, Germany) and G. Wefer

In the eastern South Atlantic the Benguela Current with its coastal upwelling branch (BCC) and the warm oceanic part (BOC) is considered an important link in the global thermohaline circulation cell associated with the formation of NADW. Two conflicting oceanographic models exist regarding the return flow into the Atlantic compensating the export of NADW: the cold water path through the Drake Passage and the warm water path around the tip of South Africa.

Planktic foraminiferal assemblages and stable isotopic ratios in sediments from the Walvis Ridge off Namibia indicate that major oceanographic changes occurred in the Southern Ocean during the past ca. 300 ky. Increased abundances of the polar species *Neogloboquadrina pachyderma* sinistral coincide with exceptionally low seasonal paleotemperatures derived from $^{18}O/^{16}O$-ratios of *Globigerinoides ruber*, white, (summer) and *Globorotalia inflata* (winter) in the surface sediments suggesting a continuous contribution of subpolar surface water to the Benguela Current system today. This is also documented in the isotope paleotemperature records during interglacial substages 7.4, 7.2, 5.5 and 5.1. Coiling ratios of *Neogloboquadrina pachyderma* sinistral to dextral with "polar" values of 50% and greater are found in glacial and interglacial sediments of the younger part of the section after Termination II and they are not documented in the isotope paleotemperature records. These "polar" ratios are considered to reflect episodic influxes of polar surface water masses, which most probably occurred in the spring when coastal upwelling is most intense.

The onset of the occurrence of these events coincides with minimum seasonalities that are due to a continuous increase in winter temperatures during isotopic stages 8-6. Based on this evidence long term alternations in the return flow route between the cold and the warm water path are proposed. These changes are not controlled by the glacial/interglacial cycle, but rather suggest a threshold effect of oceanographic parameters. Major variations in the seasonality of the wind stress over the South Atlantic and Indian Ocean causing the reorganization of the current systems in the area of the Subtropical and Polar Front are expected to play an important role.

MARINE PALYNOLOGY IN THE NEOGENE NORTH ATLANTIC: A COMPARATIVE STUDY ON THE WESTERN AND EASTERN BASIN

K.U. Schmidt (GEOMAR, Kiel, Germany)

Samples of Neogene sediments of Site 603, Leg 93, and Site 552, Leg 81, were palynologically investigated on their content of organic microfossils. The described marine microfloras were correlated with palynostratigraphic investigations from other DSDP/ODP-Legs and compared with the stratigraphic syntheses of the leg reports.

Neogene stratigraphy of Site 603, Leg 93 could be highly refined on the use of dinoflagellate cysts. For the first time there is strong evidence for Early Miocene by the occurrence of dinoflagellate cysts with ranges from Paleogene to Early Miocene. The Early Miocene/Middle Miocene boundary is located between the LO of *C. cantharellum* (Early Miocene) and the FO of *L. truncatum* (Middle Miocene) at 594 mbsf. The boundary between Middle Miocene and Late Miocene is placed more precisely as in the cruise synthesis above the FO of *A. andalousiense* (575 mbsf). The Miocene/Pliocene boundary defined by the LO of *H. obscura*, *I. aquaeductum* and *P. golzowense* at 314 mbsf confirms the nannofossil boundary. Due to the drilling procedure, the Pliocene/Pleistocene boundary could not be investigated and Pleistocene dinoflagellate cysts were found only in the uppermost core.

Dinoflagellate cyst associations found in Neogene sediments of Site 552, Leg 81 differ clearly from the ones of Site 603, Leg 93. This reflects the different geographic and oceanographic situations of both locations during the last 25 Ma. While the nearby North American continental shelf takes strong influence on Site 603 during the Neogene, Site 552 reflects the consistent pelagic conditions at the Rockall Plateau during that time. This is documented not only by different contents of dinoflagellate cysts per g sediment, which are 100-200 times lower at Site 552 as at Site 603, but also by the high dominance of *N. labyrinthea*, a pelagic dinoflagellate cyst, in Rockall Plateau microfloras.

Dinoflagellate cyst stratigraphy confirms the results of the leg report of Leg 81. There is for the first time evidence for Middle Miocene with the occurrence of *L. truncatum* (FO 150,06 mbsf) by dinoflagellate cysts. Above 134 mbsf dinoflagellate cyst associations show a Late Miocene age for these sediments.

CARBON-13 DEPLETED WATER MASS IN THE NORTHERN NORTH ATLANTIC IN THE EARLIEST EOCENE

B. Schmitz (Chemical Paleoceanography, Univ. of Göteborg, Sweden)

Anomalously low $\delta^{13}C$ values have been measured in the earliest Eocene Røsnæs Clay Formation in Denmark. Benthic foraminifera *Oridorsalis umbonatus* give $\delta^{13}C$ values as low as -3.8 ‰. The $\delta^{13}C$ anomaly occurs in sediments containing abundant ash layers from the Thulean volcanism. Unique explosive basaltic eruptions during the rifting between Greenland and Europe resulted in formation of more than two hundred ash layers over at least six million square kilometers in the northern North Atlantic region. The close association of the carbon isotopic anomaly with the basaltic ash layers indicates a connection. Possibly, release of excess, isotopically light, magmatic CO_2 to the northern North Atlantic induced low $\delta^{13}C$ values in the water mass. Bottom-water $\delta^{13}C$ values are about 2-3 ‰more negative than in the rest of the world ocean at the same time. Restricted exchange of bottom water between newly formed northern North Atlantic isolated ocean basins and the world ocean may explain the great difference in $\delta^{13}C$ values.

The negative carbon isotope anomaly is more pronounced for benthic foraminifera than for deep-water planktonic *Subbotina linaperta*. This argues against a biological productivity crisis as cause of the $\delta^{13}C$ anomaly.

MIOCENE MAGNETOSTRATIGRAPHIC RESULTS FROM OCEAN DRILLING PROGRAM LEG 138: NEW EVENTS REFINE THE GEOMAGNETIC POLARITY TIME SCALE

D.A. Schneider (Woods Hole Oceanographic Institution, Woods Hole, MA, USA)

In conjunction with biostratigraphy, the study of magnetostratigraphy provides detailed age control for the paleoceanographic analysis of many deep-sea sediment sequences. The magnetostratigraphic method requires that the reversal pattern determined for the sediment column be correlated to the known polarity sequence derived from sea-floor spreading anomalies. Complications in this process commonly arise from difficulties in the recovery of reliable magnetostratigraphic results; however, ODP Leg 138 sediments proved largely amenable to magnetostratigraphic study. Indeed the good quality, excellent stratigraphic coverage and relatively high resolution of much of the magnetostratigraphic data reveal details of the geomagnetic polarity reversal record not included in many of the currently accepted polarity timescales.

In particular, Miocene age sediments recovered during Leg 138 show seven short events which are not included in the shipboard standard time scale (Berggren et al., 1985). Four of these events appear to be short, full polarity intervals; three are more likely intervals of anomalously low geomagnetic intensity. Three of the short, full polarity intervals and one of the intensity lows can be correlated with subtle features newly recognized in the sea-floor polarity record (Cande and Kent, in press). The Cande and Kent chronology suggests that these 7 events occurred at approximately 7.0, 7.2, 8.0, 8.5, 9.0, 9.8, and 11.1 Ma. Although similar short duration geomagnetic events are relatively well-documented for the more recent parts of the record, evidence for such occurrences through the Miocene has previously been sparse.

All these magnetostratigraphic features, whether they reflect bona fide short polarity intervals or intervals of lowered geomagnetic intensity, impose an added character to the geomagnetic polarity reversal time scale. Clearer recognition of this characteristic pattern helps to identify the various polarity zones in recovered sections (something particularly difficult for the geomagnetically "busy" Miocene epoch) and improves the prospects for achieving accurate Miocene deep-sea sediment chronologies in the future.

PRECESSIONAL FORCING OF PALEOPRODUCTIVITY IN THE EASTERN ANGOLA BASIN

R. Schneider (University of Bremen, Germany), P.J. Müller, and G. Wefer

Late Quaternary paleoproductivity variations in the eastern Angola Basin, deduced from sedimentary, organic carbon accumulation, exhibit a strong 23,000 year periodicity. This periodicity is superimposed on interglacial-glacial cycles with enhanced and reduced paleoproductivity during cold and warm climate conditions, respectively. In contrast to the coastal upwelling region off NW Africa, paleoproductivity in the oceanic upwelling region off Congo and Angola also increased during the cold substages within the interglacials.

Times series analyses show that paleoproductivity changes are coherent with the earth's precessional cycling. In general paleoproductivity was high at great earth-sun distances (boreal summer aphelion), when the monsoonal wind system was weak over central Africa, causing an increase in zonal trade wind intensity above the eastern Angola Basin.

Phase relationships for the 23,000 year period revealed that maximum paleoproductivity in the eastern Angola Basin lags maximum precession by 2,500 to 4,500 years. It also lags maximum upwelling and maximum zonal wind intensity in the Equatorial Atlantic (McINTYRE et al.1989) by 1,000 to 2,000 years. Paleoproductivity changes are in phase with variations of past sea-surface temperatures in the eastern Angola Basin (poster RUHLAND et al.) and in the Cape Basin (IMBRIE et al. 1989). Based on these phase relationships we suggest that zonal intensity of the trade winds forced the shallowing of the thermocline, resulting in increased upwelling of nutrient-rich subsurface water masses off Congo and Angola. However, maximum paleoproductivity was not reached before northward advection of the cold, nutrient-rich Benguela Coastal Current was at maximum. The phase lag between paleoproductivity and precession changes results from the delay in the response of wind and ocean surface circulation to global insolation changes.

GEOCHEMISTRY OF SILURIAN AND EARLY DEVONIAN BLACK SHALES AND CHERTS (GRAPTOLITENSCHIEFER) FROM THURINGIA AND SARDINIA

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Silurian and Early Devonian black shales (Graptolite Shales) and black cherts from the Mediterranean Subprovince (Thuringia, France,Spain, Sardinia) are characterized by high contents of organic carbon, sulfur and elevated trace element content. On average the Thuringia sequence is enriched, relative to normal marine shales with low organic carbon, in: Zn, Pb (1-2 fold); Ni, Cu, Cr, Ba (2-10 fold); Mo, V, U,Co, As, Cd, Hg (10-50 fold); Ag, Sb, Se (50-200 fold). In borehole samples, where no sulfide weathering has taken place, the Mn/Fe ratio on average is 0.006 (shales <1% $C_{org.}$: 0.013) indicating a loss of Mn relative to Fe. Negative Ce-anomalies were found in the black cherts, as well as in the black shales.

Most possibly these sediments were deposited under reducing conditions in the presence of abundant H_2S. An anoxic deep ocean or anoxic outer-shelf environment is necessary to prevent organic matter oxidation and to produce syngenetic pyrite by bacterial reduction of ocean-derived sulfate. Syngenetic pyrite and other metal sulfides, which were precipitated from the anoxic water column, would also explain the high concentration of trace metals in these sediments. During the Silurian wide continental areas were flooded and black shale deposition most probably occurred in epicontinental seas.

Extremely high trace metal concentrations in some locations (e.g., Zn, Cu, U) were produced by secondary processes (redistribution during dynamo metamorphism, contact metamorphism,supergene alteration). The black shales and cherts from surface outcrops mostly are depleted in sulfide component (lower content of Fe, S, Mo, Ni, Cu, Zn, Ag, Cd, Co, As, Se).

$^{230}TH_{ex}$ FLUX AND $^{10}BE/^{230}TH_{ex}$ RATIOS IN SEDIMENTS FROM THE NORWEGIAN SEA

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The distribution of the natural radionuclides ^{230}Th and ^{10}Be in marine sediments can be used to establish and evaluate sedimentation models. These models can give informations on sediment focussing, sediment erosion and the particle fluxes through the water column during geological history. ^{230}Th and ^{10}Be measurements were conducted on long sediment cores from the Norwegian Sea. For these cores and independent time scale ($\delta^{18}O$ stratigraphy) is available which allows the calculation of radionuclide fluxes during the past 300,000 years. When the measured $^{230}Th_{ex}$ fluxes (Fa) in the sediment cores are compared with the expected ^{230}Th flux (Fp; Fp is assumed to be roughly the production rate of ^{230}Th from the radioactive decay of ^{234}U) it can be concluded, that sediment accumulation in the Norwegian Sea is largely controlled by sediment focussing and/or sediment erosion. There appears to be no influence on the $^{230}Th_{ex}$ flux due to climatic variations.

$^{10}Be/^{230}Th_{ex}$ ratios indicate strong variations of the particle flux during the past 300,000 years. There is generally a good correlation between high $^{10}Be/^{230}Th_{ex}$ ratios (indicating high particle flux) and assumed upwelling periods in the Norwegan Sea. At about 14,000 and 135,000 yr B.P. high Fa/Fp ratios correspond with low $^{10}Be/^{230}Th_{ex}$ ratios. It is proposed that these $^{230}Th_{ex}$ "anomalies" are caused by changes in water mass characteristics in the Norwegian Sea.

RECENT NORTH ATLANTIC MARINE PLANKTONIC DIATOM SEABED DISTRIBUTION: PALEOCEANOGRAPHIC SIGNIFICANCE

H. Schrader (Dept. of Geology, Bergen, Norway) and L.H. Burckle

Marine planktic diatom abundances in North Atlantic (north of 20° S and south of 70° N latitude) sediment surface samples (approximately 800 samples) do not mirror primary productivity in surface waters. Autochthonous pelagic sediments underlying surface water primary productivity areas with less than 30 gC/m2/year do generally not contain diatoms, whereas sediments underlying mesotrophic and eutrophic areas do contain marine planktic diatom assemblages.

Abundant to common and well to moderate preserved diatom floras did occur in 152 samples; a total of 37 different marine planktic diatom species and species groups were distinguished in these samples.

Q-mode factor analysis of diatom floral census data from 145 samples yielded 9 factors explaining 95.2% of the variance. These factors are (1) *Thalassiosira oestrupii*, (2) *Azpeitia nodulifer*, (3) *Paralia sulcata*, (4) *Rhizosolenia styliformis*, (5) *Thalassiosira gravida* (resting stages), (6) *Rhizosolenia bergonii*, (7) *Thalassiosira kryophila*, (8) *Thalassionema nitzschioides* and (9) *Nitzschia marina*. Mapping of individual factor loadings distribution displays a good correspondence to different hydrographic surface water regimes.

Transfer functions are defined for surface water temperatures, and surface waters salinities for the months January (standard error of estimate adjusted for degrees of freedom for temperature is 2.86 and for salinity 0.57), February (2.89, 0.52), March (2.88, 0.52), June (2.56, 0.66), July (2.59, 0.66), and August (2.75, 0.65) using as surface water calibration the NOAA Levitus data base.

The transfer function defined for surface water primary productivity (covering a range of 30 to 95 gC/m^2/year using the Berger et al. Dahlem map, 1989) and diatom factor loading seabed distributions has a standard error of estimate of 8.76 gC/m^2/year.

SEA-SURFACE TEMPERATURES IN THE NORTH ATLANTIC DURING THE EARLY HOLOCENE SUMMER INSOLATION MAXIMUM, 9000 YEARS B.P.

H. Schulz (Geological-Paleontological Institute, Christian-Albrechts Univ., Kiel, Germany) and U. Pflaumann

Two different statistical techniques were employed to reconstruct the early Holocene sea-surface temperature (SST) pattern of the North Atlantic from planktic foraminiferal assemblages. The new set of formulas for the Atlantic Ocean (Pflaumann, 1992, EPOCH-Formula) is based on transfer function, analysis (CABFAC) and on the Modern Analogue Technique (MAT). Age control of more than 60 records, including published data, came from oxygen isotope stratigraphy and AMS radiocarbon ages.

Summer SSTs in the North Atlantic and in the Norwegian-Greenland Sea were largely similar to today, in spite of the fact that summer insolation was considerably more intensive at 9,000 years B.P. Significant temperature anomalies were linked to the boundary currents of the North Atlantic. Postitive anomalies (+3-5 °C) marked the Gulf Stream near 30-35 °N, colder SST (-3-5 °C) in the Canary Current along the northwest African coast.

From this pattern, we assume that the early Holocene boundary currents were much enhanced, possibly because of stronger meridional atmospheric circulation. Strong meridional circulation is also suggested by cold SST anomalies reflecting intensified upwelling off northwest Africa.

FRACTAL ANALYSES OF SEDIMENTARY DEEP-SEA RECORD SHOW EVIDENCE FOR NON-LINEAR BEHAVIOR OF THE EARTH'S CLIMATE SYSTEM (LEG 104 SITE 643, NORWEGIAN SEA)

M. Schulz (GEOMAR, Kiel, Germany), T.C.W. Wolf, and J. Thiede

A continuous undisturbed Pleistocene sedimentary record of oxygen isotope data, calcium carbonate data and coarse fraction data from ODP Leg 104, Site 643 was investigated in the frequency domain to obtain information about possible fractal distribution of the sedimentary record.

The results of the spectral analyses demonstrate the presence of the orbital frequencies in the Milankovitch band, with mean periods at 100, 41, and 21 kyr.

The fractal dimension D was determined by a power spectral method. All parameters show clear evidence for an underlying fractal Brownian process on a 95% confidence level, i.e., $1 < D < 2$. The $CaCO_3$ signal shows a persistent behavior ($D = 1.37 \pm 0.10$), whereas the $\delta^{18}O$ signal seems to be antipersistent ($D = 1.63 \pm 0.09$). The fractal dimension of the terrigenous component ($D = 1.51 \pm 0.09$) is ambiguous in terms of possible underlying persistence.

In addition, we compared the $\delta^{18}O$ record of the Norwegian Sea with $\delta^{18}O$ records from the eastern equatorial Pacific (cores RC 13-110 and V 19-27; MIX et al., 1991). The fractal dimensions of these records have been estimated to be $D = 1.63 \pm 0.08$ and $D = 1.45 \pm 0.10$ on a 95% confidence level.

Climatic variability in the late Pleistocene can be regarded as response to periodically changing solar insolation, due to orbital forcing at distinct frequencies in the Milankovitch band. If the coupling between solar insolation and the Earth's climate system were strictly linear, then one would expect only these driving frequencies to occur in the geological record. In addition, resonance frequencies of the climate system would appear. Such a record would not be scale invariant and, hence, the record would not be fractal.

A possible explanation for the observed scale invariance is a non-linear coupling between incoming solar energy and the climate system. Then, the response of the climate system can include harmonic and subharmonic components of the driving frequencies. Beside these harmonic components, combination tones can be produced.

We suppose that the creation of these additional frequencies is responsible for the observed scale invariance of the proxy records in the frequency range between 1/125 and 1/6 kyr^{-1}. Hence, the fractal property of the sedimentary record might be an expression of the non-linear response of the climate system to driving solar insolation at distinct frequencies.

Mix, A.C., Pisias, N.G., Zahn, R., Rugh, W., Lopez, C., and Nelson, K., 1991, Carbon 13 in the Pacific Deep and intermediate Waters, 0-370 Ka: Implications for ocean circulation and Pleistocene CO_2. Paleoceanography, vol.6, no.2: 205-226.

HIGH RESOLUTION ANALYSIS OF THE CARBONATE-RICH SEDIMENT CORE 74P FROM THE ONTONG-JAVA PLATEAU (WESTERN EQUATORIAL PACIFIC)

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The concentrations of ^{230}Th ^{10}Be, Mn and Fe of sediment core 74P (Ontong-Java Plateau, 2500 m water depth, 540 cm length) were measured at high resolution (5 cm/sample). $\delta^{18}O$-stratigraphy of the planktonic foraminifer

P.obliquiloculata reveals a maximum age of about 270 ky. The mean sedimentation rate calculated by $^{230}Th_{ex}$ dating of 2 cm/ky is in agreement with the $\delta^{18}O$-stratigraphy. Preliminary results of the ESR-dating confirm the $^{230}Th_{ex}$ ages and $\delta^{18}O$ time marks.

The mean ^{230}Th-flux (6.9 dpm/cm^{2}ky) is consistent with the expected values from production (6.5 dpm/cm^{2}ky) although showing distinct maxima. The profile of $^{230}Th_{ex}/^{232}Th$ shows a significant peak at the boundary 5/6, which corresponds to similar observations at other localities in the Pacific Ocean.

The fluxes of ^{10}Be being slightly (80%) lower than expected from production.

The Mn-profile shows different variations. In comparison with the mean Mn-concentrations the Mn-profile shows two distinct peaks at at an age of 6,200 and 11,200 y B.P. The older peak marks the transition of isotope stage 2/1 whereas the younger one can be interpreted as an effect of diagenetic remobilization at the redoxcline.

A comparison of the radionuclide profiles with the concentrations of Fe and Mn in the core may help to understand the ^{230}Th flux into the sediments throughout the last 270 ky.

NUMERICAL MODEL FOR THE OCEAN PALEOCIRCULATION STUDIES

D. Seidov (P.P. Shirshov Institute of Oceanology, Academy of Sciences, Moscow, Russia, and Geological-Paleontological Institute, Kiel, Germany)

As it has been shown using an intermediate model of the ocean general circulation (IOGCM), applied by the author to Mezozoic-Cenozoic ocean currents reconstruction (Seidov,1986), numerical modelling should follow some important general principles. The problem of constructing generalized schemes of paleo-patterns using these principles is being revisited. A new version of the IOGCM was designed to meet the main necessities of the ocean paleoclimate reconstruction. The model is based on the assumption that motion in the ocean is predominantly geostrophic. A novice feature of the model is the parameterization of side boundary layers to ensure second order dynamics. The model was tested in a pilot study designed to mimic well-documented results of primitive equation models. Special attention was drawn to upwelling at the basin margins, since the lack of upwelling has been main deficiency of model incorporating geostrophy as the dominant physical signature.

Performance of the model is illustrated by Mezosoic and Cenozoic schemes of water masses circulation, and by some other, more recent examples. A number of global changes in the ocean paleoclimate can be easily explained in terms of an equilibrium between blocking zonal currents and pools of warm water inside anti-cyclonic subtropical gyres, and there is very strong dependence on the basin geometry on a geological time scale. The ocean climate system can also appear to be very sensitive to change in thermodynamic regime in high latitudes on a much shorter time scale. An approach to this problem using 1O GCM is also discussed.

TOWARD A BETTER UNDERSTANDING OF THE NORTH ATLANTIC RESPONSE TO THE MELTWATER EVENT NEAR 13.6 KA - A NUMERICAL OCEAN CIRCULATION MODEL

D. Seidov (P.P. Shirshov Institute of Oceanology, Moscow, Russia, and Geological-Paleontological Institute, Kiel, Germany), I. Yushina, M. Sarnthein, and K. Stattegger

The ocean response to local changes in winds and themohaline conditions of the surface is not yet well understood. The rates and scales of changes of the ocean currents and the thermohaline structure are of primary interest for identifying the spreading of low-salinity waters. Therefore, we tested a paleoreconstruction of a major meltwater event subsequent to the Last Glacial Maximum (LGM). The $\delta^{18}O$ maps reveal steep salinity gradients formed in subpolar regions of the eastern North Atlantic at that time. We modelled the North Atlantic ocean large-scale circulation using model winds for 18 ka BP simulated by Lautenschlager'and Herterich in the framework of T21 atmospheric GCM. Special attention was paid to shifts of the polar front, linked to strong melt water injection 13,600 years ago. The main interest was directed to the problem of possible switches of water overturn process and its connection to the changes in circulation in the subtropical North Atlantic. Preliminary results of our numerical study indicate noticeable changes in the position of the isopycnal outcrops, which mark the thermohaline fronts. Changes in the overall currents system also suggest, in harmony with the results of proxy data reconstructions, that variation of the surface salinity in subpolar eastern North Atlantic might have triggered a switch in the Atlantic salinity conveyor.

MAGMATIC EVOLUTION OF THE URAL PALEO OCEAN

I. Seravkin (Institute of Geology, Bashkir Scientific Center, Ural Division, Academy of Sciences, Ufa, Russia)

The Paleozoic ocean in the Urals is indicated by geologic formations: I) shelf and bathyal complexes of the East-European plate margin preserved at the western slope of the Ural; 2) fragments of the ocean-type crust (ophiolite triad) occuring within the melange of the suture zone and major thrusts; 3) arc volcanogenic formations of the Magnitogorsk belt; 4) volcano-plutonic formations of continental-marginal belts in the eastern zones. All these units form an asymmetrical magmatic, facial and metallogenic zonation that shows both western passive and eastern active contintental margins corresponding to D_{2-3} to be present.

The evolution of chemical composition in volcanic rocks according to main and satellite elements (Rb, Sr, Ni, Cr, Co, Ti, Zr, REE, etc.) suggests the most complete development of J. Wilson´s cycle. Splitting of the continent was accompanied by eruptions of trachibasalts (C-O) while spreading of the volcanic basin - by mass effusions of ocean-type tholeiites (O-S); development of submarine riftogenic structures - by contrast ryolite-basaltic volcanism (S); subduction along the eastward dipping Benyoff zone - by arc volcanogenic formations of alkali-lime and shoshonite series (D_{2-3}); and collision - by volcano-plutonic subalkali and alkali-lime Andes-type belts (C_{1-2}) as well as intrusions of granite batholites (PZ_3).

Latitudinal variations in composition of synchronous riftogenic and arc volcanogenic complexes have been recognized. Facial zonation, approximate evaluation of rate under spreading and chemical behaviour of ancient versus

modern volcanic rocks show that the Ural paleoocean reached 1,000 km in width.

Shield volcanoes, stratovolcanoes, calderas, extrusive domes, etc., have been reconstructed in the arc formations. Composition, texture of the formations and eruption types for the paleovolcanoes were similar to those for modern arc systems.

AN ASTRONOMICALLY CALIBRATED PLIOCENE TIME SCALE BASED ON LEG 138 GRAPE DENSITY RECORDS

N.J. Shackleton (Godwin Lab, Univ. of Cambridge, UK), S.J. Crowhurst, N. Pisias, T. Hagelberg, D.Schneider, A. Mix, and ODP Leg 138 Shipboard Scientific Party

Aboard ship an outstanding achievement of ODP Leg 138 was the compilation of high quality, continuous, complete GRAPE (Gamma Ray Attenuation Porosity Evaluator) density records for each site. Density reflects %carbonate and the sites were correlated with precision aboard ship using GRAPE-, bio- and magneto-stratigraphy. The GRAPE records show cyclicity in the bandwidth of variations in the Earth orbital geometry.

In Site 849 we have used a $\delta^{18}O$ record generated at OSU and correlated to the $\delta^{18}O$ record of ODP Site 677 (Shackleton, Berger, and Peltier, 1990) to provide a Pleistocene time scale; in addition we have generated a $\delta^{18}O$ record for the Pliocenesection of Site 846 in Cambridge, but below the mid-Gauss the $\delta^{18}O$ record has too poor a signal-to-noise ratio to enable a convincing time scale to be generated from it alone.

Instead we have generated a time scale by correlating GRAPE density to insolation at 65°N (Berger and Loutre, 1991). We have used data from Sites 846, 847, 849, 850, 851 and 852 to provide a robust chronology. Lacking a model that predicts appropriate time constants for the response of the Pacific carbonate system to orbital forcing, the time scale has an inherent uncertainty of a few thousand years; other than that, the match is statistically and visually good enough to suggest that it is probably correct in detail to 6 Ma. Ages for the bounds of the Kaena and Mammoth subchrons agree extremely well with the revised marine magneticanomaly time scale of Cande and Kent (in press), as well as with the estimates obtained by Hilgen (1992) based on astronomical calibration of sedimentological cycles in Italy. Below that it is only possible to achieve an acceptable match with orbital insolation by deviating to a significant degree from the time scale of Cande and Kent (in press). Our ages for the Gilbert-Gauss boundary (3.61 Ma) and for the Cochiti (4,188 to 4,320 Ma) are close to those estimated by Hilgen (1992). Below this our time scale relies on correlation between well-tuned records and the lower-resolution Site 852 which faithfully records the palaeomagnetic signal. Our estimates remain close to those of Hilgen (1992) and we obtain an age of about 5,875 Ma for the top of C3A.

OXYGEN ISOTOPE STRATIGRAPHY OF THE PLIOCENE IN ODP SITE 846

N.J. Shackleton (Godwin Lab, Univ. of Cambridge, UK), M.A. Hall, L. Mayer, N. Pisias, and ODP Leg 138 Shipboard Scientific Party

The successful compilation of composite sections aboardship during ODP Leg 138, based on the GRAPE density records (see Hagelberg et al. poster),

enormously aided the efficiency with which sampling could be planned for high-resolution stable isotope studies. We have generated a high-resolution benthonic oxygen isotope record for Site 846 with demonstrated continuity at an average sampling interval of 2,500 years. For the Olduvai-to-Gauss interval the data confirm the validity of the records of DSDP Site 607 (Raymo et al., 1989) and ODP Site 677 (Shackleton, Berger and Peltier, 1990).

Within the Gauss, the first "glacial" cycles that are significantly more positive than today are around the Mammoth event. In the lower Gauss the peak-to-peak range of variation is typically about 0.5 per mil, the whole range being isotopically lighter than present-day values. One possible explanation for this would be that the record reflects glacial-interglacial fluctuations on Antarctica. The Gilbert includes some intervals with very low-amplitude variability, but distinct cycles at the Sidufjall Event have an amplitude of 0.8 per mil and the two glacial extremes probably require either a little northern-hemisphere glaciation or an Antarctic ice sheet slightly larger than is present today, associated with deep water as cold as today's. In contrast a conspicuous interglacial peak close to the Thvera Event is a full 1per mil lighter than these Sidufjall glacial events.

If the astronomically tuned time scale based on GRAPE density variations (Shackleton et al., poster) is applied to the oxygen isotope record (1) through the whole Pliocene there is a marked growth in the oxygen isotope response at orbital frequencies, whereas the GRAPE density response is more consistent over the interval and (2) comparing isotope and GRAPE variance spectra shows that there is proportionally more response to tilt than to precession in the isotope record. This mirrors the observation that in Site 677 the planktonic oxygen isotope record, reflecting equatorial Pacific surface-water oceanography, displays a greater response to precession than the benthonic record.

OXYGEN ISOTOPES IN BIOGENIC SILICA: GLACIAL - INTERGLACIAL VARIATIONS IN TEMPERATURE AND SEAWATER ISOTOPIC COMPOSITION

A. Shemesh (Dept. of Environmental Sciences, Weizmann Institute of Science, Rehovot, Israel)

The oxygen isotopic composition of biogenic opal is determined by the temperature and the isotopic composition of seawater from which it was deposited. The slope of the opal paleotemperature equation differs from that of the carbonate paleotemperature equation. Thus, by measuring the isotopic composition of two co-existing marine phases, diatom opal and foraminiferal calcite, it is possible to calculate two independent variables: temperature and isotopic composition of seawater. These variables provide crucial information about changes in the marine and continental environments during stages of climate change and ice-cap melting.

The first record of oxygen isotopes in biogenic silica from a Southern Ocean deep sea sediment core reveals that marine diatoms maintain their primary isotopic composition after burial, allowing their use as monitors of past sea surface temperature and isotopic composition of surface seawater. The coupling of oxygen isotopes measurements from diatoms with those from coexisting planktonic foraminifera was applied to a core (RC13-271) from the South Atlantic. The results show that while strong cycles of both the local temperature and oxygen isotopic composition of seawater are apparent, the average $\delta^{18}O$ during the glacial period at this site was about 1.3‰ higher than average recent (Holocene) values, close to the global ice volume effect calculated from the Barbados coral sea level record and deep sea foraminifera. The corresponding temperature change is only 1°C indicating that average

glacial-age temperatures at this site were not significantly different from average Holocene values. The same isotopic pattern is repeated in a nearby core, RC13-269, indicating that opal can be used to detect regional paleoceanographic signals.

BARIUM PALAEOPRODUCTIVITY RECORDS FROM MESOTROPHIC OCEAN MARGIN PROVINCES RECORDED OVER THE LAST 250,000 YEARS

G.B. Shimmield (Marine Geosciences Unit, Univ. of Edinburgh, Scotland, UK), S. Derrick, D. Kroon, J. Lloyd, G. McNeill, and A. Matthewson

By using a combination of high precision X-ray fluorescence analysis of bulk sediment barium content and $\delta^{18}O$ isotope stratigraphy on selected foraminifera, we have been able to reconstruct records of barium content, and flux, at ocean margins over the last 250 ky. Selected sites from the Pacific (Nazca Ridge), Atlantic (west Spitsbergen and northwest Africa), Indian Ocean (Arabian Sea) and Southern Ocean (Weddell Sea and Scotia Sea) have been studied using timeseries analysis of piston and ODP-HPC cores. Ba is known to accumulate in micro-environment interstices of sinking diatom tests. The abundance of barium in hemipelagic sediments is therefore proportional to the overall biogenic flux of barium through the water column. Due to excellent preservation of barium under oxic/suboxic conditions, a palaeoceanographic record of (siliceous?) palaeoproductivity results. Our data indicates that such records reveal important evidence for reorganisations of oceanic nutrients over glacial/interglacial episodes. The abundance of barium in the sediment is closely tied to the $\delta^{18}O$ record, displaying pronounced 100 ky periodicity with coherent forcing response at both 41 and 23 ky cycles. In the Arabian Sea, southwest Pacific and Southern Ocean, south of the polar front, Ba contents increase dramatically in interglacial sediment. Off northwest Africa, barium is closely related to the organic matter maximum during the last glacial episode (and stage 6). Barium records ice-melting events and associated productivity in both the Norwegian-Greenland Sea and Weddell Sea. Comparison with records of biogenic silica and organic carbon allow us to identify conspicuous phase shifts in these biogenic palaeoproductivity markers in high-accumulation rate cores.

PALEO DISCHARGE EVENTS ON THE AMAZON FAN

W.J. Showers (Dept. of Marine, Earth and Atmospheric Sciences, North Carolina State Univ., Raleigh, USA), B. Genna, and J. Karr

$\delta^{18}O$ stratigraphies on the Amazon Fan of *G. sacculifer* from piston cores located in overbank deposits on the upper and middle fan have negative deviations from the average western tropical Atlantic signal. These negative $\delta^{18}O$ spikes have been interpreted a Amazon River paleodischarge events. Eastern levee complex stratigraphies have paleodischarge events of 0.5 to 1.5 per mil magnitude, but these events are absent from the western portions of the fan. The Amazon fan was resampled during May-June 1991 with a giant gravity core from FS Meteor. Paleodischarge events were found in the eastern levee omplex from these cores, and the lateral extent east and west were defined. The spatial focusing of the paleodischarge events on the eastern levee complex does not fit with the modern western equatorial Atlantic surface circulation

pattern, which advects present day Amazon River water to the northwest across the equator as part of the global conveyor system. Why does the Amazon River turn right during the last low stand? Three factors may be important in this low stand circulation change 1) a change in the beta effect as the low stand river mouth moves to 3-4°N, 2) a change in the wind stress vector as a result of a change of the orientation of the lowstand coastline, 3) a change in the global conveyor circulation. The last factor would occur if a permanent NBO retroflection developed during the last glacial low stand. When the modern current retroflection pattern (defined by satellite drifters) is moved the distance offshore that the coastline moves, the surface paleo-current pattern matches the distribution of paleodischarge events recorded in fan sediments. The change in western tropical Atlantic circulation and cessation of cross equatorial transport is most likely controlled by sea level changes. Reinitiation of cross equatorial tranport and modern conveyor circulation occurs when the Barbados coral record records the most rapid deglacial sea-level rise.

SANDY CONTOURITES OF THE RECENT AND LATE MIOCENE ATLANTIC-MEDITERRANEAN GATEWAYS. WHAT DO THEY MEAN?

F.J. Sierro (Universidad de Salamanca, Spain) and J.A. Flores

The calcareous plankton associations of several late Pleistocene-Holocene gravity cores of the Gulf of Cadiz margin were analyzed in order to recognize the main paleoceanographic changes related to the Atlantic Mediterranean connection. The general sedimentary features were compared with those recorded in the late Miocene deposits of the North Corridor.

Both Holocene and Tortonian sediments were deposited on the northern margin of the recent and old Atlantic-Mediterranean gateways during cycles of global sea-level rise. In both cases, the clay hemipelagic sediments are interlayered with silty and sandy contourite deposits. The Gulf of Cadiz sandy contourites have been related to episodic increases in intensity of the MOW (Mediterranean Outflowing Waters) which in many cases coincide with relative sea-level rises (Faugeres et al., 1986; Nelson et al. in press.).

After comparing these Holocene and late Tortonian deposits we believe that the fluctuations in the rate of eustatic change could also explain the formation of the sandy layers, at least partially. Keeping constant through time the energy of the current sweeping the bottom, the reduction of the sedimentation rate during the times of maximum flooding would have caused an increase of the time during which the same energy was acting on the mixed layer of the surface sediment . At the same time, the effect of the biogenic reworking due to the activity of the infaunal benthic communities would have been stronger since more successive generations of organisms were mixing and disaggregating particles in the same layer.

According to this, during the times of maximum rates of relative sea-level rise, the energy as well as the biogenic reworking per unit of aggradated sediment , increase leading to an evident textural change in the sediment. Therefore, these sandy contourites could be seen as condensed layers not necessarily related to intensifications of the MOW.

CHANGES IN THE SOUTHERN OCEAN OVER THE LAST 22 KY: A VIEW FROM THE CHATHAM RISE

E.L. Sikes (Univ. of Tasmania, Hobart, Australia), H.L. Neil, and S.D. Nodder

The subtropical convergence (STC) is the northern boundary of the Southern Ocean. Previous studies have shown that this boundary changes its north-south position coincident with glacial to interglacial scale climate changes. The position of the STC over the Chatham Rise (to the east of New Zealand) is unusually far north relative to its location in other parts of the Southern Ocean where it is a well-defined front. It has been suggested that presently, the STC is trapped bathymetrically in its position by the Chatham Rise.

Cores were obtained from two north-south transects either side of the STC (and the Chatham Rise). Initial stable isotopic results from planktonic foraminifera suggest that the STC remained fixed over the Chatham Rise at the last glacial maximum. Our preliminary results agree with the results of other studies that indicate the STC remained over the Chatham rise through isotope stages 1-6. If the Chatham Rise is controlling the location of the STC today, it may be such a strong influence that it can maintain the present position of the STC east of New Zealand during major climate change, despite large movement of the STC and other major Southern Ocean fronts northward in the last glaciation.

CALIBRATION OF LONG-CHAIN ALKENONE UNSATURATION RATIOS FOR PALEOTEMPERATURE ESTIMATION IN COLD POLAR WATERS

E.L. Sikes (Inst. for Antarctic and Southern Ocean Studies, Univ. of Tasmania, Hobart, Australia) and J.K. Volkman

The ratio of di- to di- plus tri-unsaturated long-chain C_{37} methyl ketones synthesized by certain prymnesiophyte microalgae has been shown to vary linearly with the sea-water temperature in which the organisms grow over the range 8-25°C (1,2). This ratio is denoted by $U^{k'}_{37}$ where $U^{k'}_{37} = (37:2)/[(37:2) + (37:3)]$ and (37:x) is the concentration of the C_{37} alkenone with "x" double bonds. $U^{k'}_{37}$ has proven to be a useful indicator of past sea-surface temperature (SST) in low to mid-latitudes (3-7). Presently, the use of $U^{k'}_{37}$ is limited to these locations because there is no field calibration for temperatures below 10°C. Here we extend the calibration of $U^{k'}_{37}$ for the first time to cold polar waters (-0.7-12°C) from the Southern Ocean. The calibration of $U^{k'}_{37}$ with temperature in field samples across the range 0-28°C is significantly different from that established from analyses of prymnesiophyte algea in culture, and diverges especially at the colder temperatures. Between 3.5-27°C the relationship is essentially linear, and can be fit by the simple equation $U^{k'}_{37} = 0.042T-0.164$. Between 5 and -0.7°C, the slope flattens and the calibration for the entire data set is better fit by a logistics curve. This calibration establishes the viability of $U^{k'}_{37}$ as an SST indicator for temperatures as low as 3.5°C.

DRASTIC CHANGES IN THE NE-ATLANTIC DEEP-SEA SEDIMENTS AND FAUNAS - PRESERVATION PATTERNS OF CALCIUM CARBONATE DURING THE LAST 150,000 YEARS (PART 2)

C. Simet (Institut für Geologie und Paläontologie, Tübingen, Germany), M. Maslin, and C. Hemleben

The fragmentation of planktic foraminiferal tests was used to determine the preservation of calcium carbonate in late Pleistocene sediments from various sites in the mid-latitudes of the eastern North Atlantic. The cores lie within a zone, which was affected repeatedly by massive ice-rafting events during glacial times, leading to the formation of rather regularly occurring horizons of high detritic and low foraminiferal content (so-called Heinrich events). Three events of enhanced dissolution were observed: A spike-like event at the top of isotope stage 3 (about 28 ky BP) and two stronger events at the lower part of stage 4 (65-77 ky BP) and within stage 6 (130-142 ky BP). They are also reflected in the calcium carbonate curve. Due to the differential dissolution, the assemblages of planktic foraminifera are altered to the effect that faunas from southern deep water locations point towards cooler temperatures than those from shallow, more northerly situated sites.

The observed variations in the intensity of dissolution coincide with the carbonate preservation patterns of the sub-tropical and tropical Atlantic except for the first dissolution event, which does not fall within time of largest ice extent but occurs before the Last Glacial Maximum. Further high-resolution investigations are necessary to clarify the question of whether this discrepancy is only due to poorly adjusted time scales, or whether it indicates a special deep-water situation in the eastern basin between 45° and 60° N at the end of isotope stage 3.

There is no correlation between the southward migrating polar front in surface waters and the changes of carbonate preservation in abyssal deep waters.

ORGANIC CARBON ACCUMULATION RATES IN THE HOLOCENE AND GLACIAL ARABIAN SEA: IMPLICATIONS FOR ATMOSPHERIC CO_2 VARIATIONS

F. Sirocko (Lamont-Doherty Geological Observatory, Palisades, NY, USA) and V. Ittekkot

Changes in the deep-sea carbon reservoir have been envoked in the past to explain variations in atmospheric CO_2 fluctuations. In this report we distinguish between the quantity of organic matter remineralized in the deep sea and that permanently removed into sediments by comparing the bulk- and organic carbon accumulation rates in Holocene and glacial sediments of the Arabian Sea with total- and organic carbon fluxes from continuous sediment trap deployments.

The comparison shows that Corg contents and flux rates in the traps are systematically higher than in the sediments and that the mass of organic carbon remineralized at the sediment-water interface is mainly a function of the bulk sediment flux and not necessarily related to the productivity of overlying surface waters. This direct relationship between organic carbon remineralization and bulk sediment flux appears to result from the mediation of mineral matter in the removal of organic matter from the sea surface to the deep ocean.

We assume that if the bulk accumulation rate (not primary productivity) influences the flux of organic carbon (that is fixed from the atmosphere by marine organisms), then mineral matter flux will exert a significant control over atmospheric CO_2 contents. Model calculations incorporating transient changes in global bulk flux, for example during times of rapid sea-level rise, show that significant proportions of observed changes in atmospheric CO_2 contents can be accounted for by this mechanism. These results also suggest that modern day changes in the drainage basins of rivers affecting the pattern of sediment discharge from land to sea may have a significant influence on future atmospheric CO_2 contents.

A STRATIGRAPHY FOR CORE 658C, ODP LEG 108, USING GREY SCALE AND MAGNETIC SUSCEPTIBILITY DATA

M.B. Smith (Organic Geochemistry Unit, Bristol Univ., Avon, UK.), M. Zhao, and G. Eglinton

Recent studies of ODP leg 108, Hole 658A&B, (Cap Blanc, North West Africa) have shown the site to be a valuable source of information for palaeoclimatic assessment through high-resolution stratigraphy. Work is proceeding on a high-resolution molecular stratigraphic evaluation of the adjacent hole, 658C. This core had been immediately deep-frozen on board ship to preserve the molecular record, and not logged or examined in any way. We now report on the first phase of a palaeoclimatic assessment of 658C, involving cross-correlation with 658A&B.

Whole-core magnetic susceptibility measurements of 658C have been carried out at 5 cm resolution and these data compared with those for 658A&B measured with similar resolution on board ship (Bloemendal *et al*). Cross-core correlation is good, thereby providing a basic stratigraphy for 658C.
Video images of all core sections from 658C were captured with the system developed by Dr. Russell Merrill at ODP/TAMU. Images have been processed to derive grey scale values at 0.5 cm resolution for each of the three component colors; red, green and blue. Visual inspection of down-core grey scale values reveals long-term oscillations comparable with those of the $\delta^{18}O$ stratigraphy for 658A&B.

Comparisons with other stratigraphic measures, including U^{k}_{37}, TOC, carbonate and silica are in progress for all three cores. Spectral evaluation of the data sets using digital signal processing, Fourier transform and other time-series methods will be reported for these cores which span the last *ca.* 400ka.

RECORDS OF ANTARCTIC TEMPERATURE, ATMOSPHEREIC CO_2 AND ICE VOLUME DURING THE LAST DEGLACIATION

T. Sowers (Graduate School of Oceanography, Univ. of Rhode Island, Narragansett, USA), M. Bender, and J.-M. Barnola

In order to better understand the nature of major climatic changes, it is useful to know the sequence of the associated events which lead to such changes. The object of the present study was to establish the timing of changes in atmospheric CO_2, surface temperatures and sea level during the last deglaciation. To do so we compared records of pCO_2, $\delta^{18}O$ of atmospheric O_2 ($\delta^{18}O_{atm}$) and the δD or $\delta^{18}O$ of ice from the Vostok and Byrd ice cores. Additionally, we have compared these ice core records with records of the $\delta^{18}O$ of foraminiferal calcite ($\delta^{18}O_{foram}$) and sea-surface temperature (SST) from deep-sea sediment cores.

We have placed all the ice core and deep-sea sediment records onto a common time scale. To do this we assume that changes in the $\delta^{18}O$ of sea water (a proxy for continental ice volume) have been transmitted to the atmosphere by photosynthesis. Changes in the $\delta^{18}O$ of sea water have been recorded in the tests of foraminifera while contemporaneous changes in $\delta^{18}O_{atm}$ are recorded in trapped gases in ice cores. We have thus placed the marine and ice core climate records onto a common time scale by correlating the $\delta^{18}O_{atm}$ and $\delta^{18}O_{foram}$ records.

By correlating the Byrd and Vostok $\delta^{18}O_{atm}$ records, the CO_2 records from these two cores overlay one another. When we place the atmospheric CO_2 record, an Antarctic temperature record from Byrd, and a Southern Ocean SST record from 46°S on our common time scale, we observe no apparent phase lag between all the records during the initial phase of the deglaciation. Our results suggest that CO_2 and sea-surface temperatures are roughly in phase with, or slightly lead (by less than 2 kyr), the initial reduction in continental ice volume. This last result differs from our result for the penultimate deglaciation which is based on the original Vostok chronology. At. the start of the penultimate deglaciation CO_2 began to increase 4.3 ± 1.7 kyr prior to the initial reduction in continental ice volume.

BENTHIC FORAMINIFERAL RESPONSE TO ENVIRONMENTAL CHANGES FOLLOWING THE K/T-BOUNDARY

R.P. Speijer (Institute of Earth Sciences, Univ. of Utrecht, The Netherlands)

In order to assess how the upper bathyal environment of the southern Tethyan margin changes at K/T-boundary time, various quantitative analyses have been performed on the benthic foraminiferal assemblages, derived from El Kef.

At the K/T-boundary, a stable, very rich and diversified Maastrichtian assemblage is replaced by a low diversity assemblage, due to the disappearance of almost 75% of the species. Few species invade the area simultaneously. In combination with the occurrence of fine laminations in the sediment, this Early Paleocene (P0/P1a) assemblage appears to indicate dysoxic bottom conditions, hostile to larger burrowing organisms. The opportunistic species *Tappanina selmensis* is the most abundant species. Bottom conditions ameliorate during the upper part of Zone P1a, as indicated by the disappearance of both the laminations and the species that invaded the area at the K/T-boundary. Moreover, many Maastrichtian species reappear, although a minor part of these went extinct. Former Maastrichtian conditions appear to have been restored during Zone P1b.

Fluctuations in primary production have been concluded from $\delta^{13}C$- and $CaCO_3$ accumulation changes. These correlate well with changes in accumulation rate of benthic foraminifera. High values during the Maastrichtian are followed by a sharp drop in the earliest Paleocene (P0), and a slight increase during Zone P1a. Dissolution of $CaCO_3$ appears to play only a subordinate role as a cause for these low values. Simutaneously with the faunal adjustment during the upper part of Zone P1a, accumulation rates increase strongly, although Masstrichtian values are not reached.

From these data it appears that at the time of Zone P1b, an oceanographic situation similar to the one in the late Maastrichtian is reached. The earliest Paleocene is characterised by bottomwater oxygen-deficiency, which is, however, difficult to combine with a prolonged period of low productivity.

STUDY OF DIACHRONEITY OF NEOGENE PLANKTON AND REVISED BIOSTRATIGRAPHY

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Out of more than 1000 Deep-Sea Drilling Project and Ocean-Drilling Program holes drilled so far, a selection of 110 globally distributed holes with reasonably complete Neogene records were used for a bio- and magnetochronological analysis. The depth below sea floor of first appearance and last appearance of several hundred microfossil species belonging to the calcareous nannofossils, diatoms, planktic foraminifera and radiolarians were compiled from the existing distribution charts of the DSDP and ODP Initial Reports. The published magnetostratigraphies of 45 of these holes were also compiled. To create a standardized reference succession, the compiled subbottom depth levels of bio- and magnetostratigraphic events were analyzed using probabilistic stratigraphy (Hay, 1970) to determine the most likely succession and a reliability index for events. Age vs. depth models for each hole were constructed. Numerical age estimates for commonly used foraminifera, nannofossil, radiolarian, and diatom events were then interpolated in each hole from their stratigraphic positions relative to the magnetochronologies. Magnetochronologic ages are from Berggren et al. (1985). Age estimates were used to study geographic patterns of diachroneity, variability in age, and most probable age for synchronous events. Most of the events do not show any consistent pattern of diachroneity: this might be due to the choice of holes used in this study (local bad recovery or preservation) or by an incomplete latitudinal coverage. Unexplained site-to-site variation in event age averages ± 0.5 Ma for most events. Some patterns are seen: many diatom and radiolarian events (both FAD and LAD) occur first in high latitudes and later in low-latitude areas. Some nannofossil events appear first in low latitudes and later in high latitudes. In general, many plankton events are diachronous: calibrations made at low latitudes may differ by several million years from their occurrence in higher latitudes and are therefore of limited global reliability.

INTRASPECIFIC STABLE ISOTOPE VARIABILITY IN THE PLANKTONIC FORAMINIFERA *GLOBIGERINOIDES SACCULIFER*

H.J. Spero (Dept. of Geology, Univ. of California, Davis, USA) and D.W. Lea

Stable isotopic analyses of the symbiotic planktonic foraminifera, *Globigerinoides sacculifer*, are used to reconstruct Pleistocene paleoceanographic events in tropical and sub-tropical deep-sea cores. Evidence from plankton tows and cores suggest that this species secretes its shell in carbon isotope disequilibrium and shows a significant size:$\delta^{13}C$ relationship. Laboratory culture experiments were conducted in order to quantify the effect of symbiont photosynthesis on shell $\delta^{13}C$ in order to explain these observations.

Small *G. sacculifer* (250-300 μm) were collected for culture from Exuma Sound, Bahamas. Individuals were maintained under three different irradiance levels at 29°C to vary symbiont photosynthetic activity during shell growth. While in culture, each foraminifera secreted 3-5 chambers on its trochospiral shell. Following gametogenesis, chambers were amputated from the shells and collected for isotopic analysis. In the case of *G. sacculifer*, most chambers had sufficient mass to be analyzed individually.

The results show that chambers grown under high irradiance levels are enriched in ^{13}C by 1.1 o 1.7 ‰ relative to chambers secreted under low light levels. This effect is due to to the preferential uptake of $^{12}CO_2$ by symbionts during chamber calcification, previously documented for *Orbulina universa* (Spero and DeNiro, 1987). Chamber $\delta^{13}C$ also increases with ontogeny. In individuals maintained under high light levels, mean chamber values increase from 1.2 to 2.0 ‰ as shell size increases form 350 to 680 μm. In contrast, chambers secreted by foraminifera in the medium and low-light groups do not display an ontogenetic effect.

No ontogenetic effect is observed among chamber $\delta^{18}O$ values in any light group. However, whereas individuals growing under high-light levels secrete their chambers in isotopic equilibrium, chambers secreted under low and medium light levels have average values that are enriched in ^{18}O by 0.5 ‰ relative to the high-light group. These latter results are in contrast to earlier experimental results on *G. sacculifer* (Erez and Luz, 1983) and suggest that under conditions of reduced symbiont photosynthetic activity, this species may secrete its shell out of oxygen isotope equilibrium.

PALEOCLIMATIC INSTABILITY ACROSS THE OLIGOCENE/MIOCENE BOUNDARY: EVIDENCE BASED ON PLANKTONIC FORAMINIFERA FROM THE "OCEANIC RECORD"

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A detailed biostratigraphic study on planktonic foraminiferal assemblages spanning the interval from Zone P21a (upper Oligocene) to Zone N5 (lower Miocene) was performed on several pelagic sequences recovered in DSDP and ODP holes. The often rich and well-preserved assemblages show that faunas fluctuate in abundance and species-richness throughout the sequences. Furthermore, distributions of some taxa differs from that reported in the literature. Assuming that fluctuations and distribution discrepancies could be sometimes related to paleoclimatic variations, quantitative analyses on planktonic foraminifera were performed (counting about 900 specimens for samples) on 269 samples from Holes 116, 538A, 667A, 516F and 360 located in the Atlantic Ocean along a N-S transect to have a latitudinal coverage (from 57° 29. 76' N to 35° 05. 79' S), and on 39 samples from Hole 709B in the Equatorial Indian Ocean (03° 54. 90' S). Climatic curves were constructed using as **1)** warmer indicators *Guembelitria columbiana*, and *Gallitellia*?, *Globigerinoides*, *Cassigerinella*, *Dentoglobigerina altispira*, *"Globigerina" ciperoensis* and *Globorotalia* s.s. groups; **2)** cooler indicators *Globorotaloides*, *Catapsydrax*, *Globigerina* s.s. groups and tenuitellids. Climatic curves show more marked fluctuations at high than at lower latitudes. Some of them are sometimes reproducible from hole to hole.

General paleoclimatic trends can be summarized as follows: **1)** warming in Zones P21b-P22 (upper Oligocene), with the warmest peak in the Gulf of

Mexico and Caribbean, followed by **2)** a cooling and strong climatic instability probably responsible for the discrepancies in distributions of some taxa, in Zone N4 (across the Oligocene/Miocene boundary) and **3)** a new warming from the upper part of Zone N4b and Zone N5 (lower Miocene).

The abundance of the upwelling indices, *Paragloborotalia kugleri, Globorotaloides hexagonus, Globorotaloides stainforthi* group and protentellids, corroborated by the presence of radiolarians, diatoms, and sponge spicules, also allowed one to identify the major upwelling pulses in subzone N4a.

MAPPING THE ARCTIC OCEAN LOW-SALINITY SURFACE LAYER BY MEANS OF STABLE ISOTOPES IN PLANKTIC FORAMINIFERS FROM SURFACE SAMPLES AND SHORT SEDIMENT CORES

R.F. Spielhagen (GEOMAR, Kiel, Germany), S.E.I. Köhler, R. Stein, H.W. Hubberten, and the POLARSTERN ARCTIC' 91Shipboard Scientific Party

Planktic foraminifers (*Neogloboquadrina pachyderma* sin.) from Arctic surface sediment samples and short sediment cores have been analyzed for stable oxygen and carbon isotopes ($\delta^{18}O$, $\delta^{13}C$). Samples were obtained during various RV POLARSTERN expeditions, including ARK IV/3 (1987) and ARCTIC '91 to the eastern and central Arctic Ocean. The data base was extended using previously published data sets.

Oxygen isotopic values show a well-expressed trend towards lighter values between the southern Nansen Basin (>3.5 ‰) and the North Pole (<1.6 ‰). This reflects the changing salinity in *N. pachyderma*'s habitat, decreasing from >33 ‰ in Atlantic waters north of the Barents Shelf to <31 ‰ of the Arctic Ocean low-salinity layer in the Amundsen Basin. Water temperatures are generally just above freezing point (c. -1.8°C in high Arctic waters). Carbon isotope values in *N. pachyderma* sin. from surface samples are in the range of 0.7-1.0 ‰ north of 84°N, with only a few exceptions. In sediment cores from the Yermak Plateau and the Gakkel and Lomonosov Ridges, oxygen isotope values of *N. pachyderma* sin. from the uppermost layer are on the level of the surface samples and represent the Holocene. The glacial-interglacial difference is 1-1.5 ‰ to underlying sediments.

Relatively heavy oxygen isotope values (c. 3 ‰) in surface samples from the vicinity of the Morris Jesup Plateau (MJP) are not in accordance with today's water-mass properties in this area. The oxygen isotope profile in a short core from the MJP shows only little variations and suggests non-deposition or erosion during the at least parts of the Holocene or even a longer interval.

ACOUSTIC STRATIGRAPHY OF MAUD RISE SEDIMENTS - A DIGITAL PARASOUND ECHOSOUNDER SURVEY AT ODP DRILL SITES 689 AND 690

V. Spieß (Univ. of Bremen, Germany)

During the RV POLARSTERN cruise ANT VIII/6 in April/ May 1990 digital seismic data were collected on a routine basis with the Parasound echosounder and the new digital data acquisition system PARADIGMA. The source frequency can be varied between 2.5 and 5.5 kHz and signal length from 0.27 to 4.8 ms. The sound energy is restricted to a narrow 4° cone providing a superior vertical resolution on the order of 10 cm as well as high lateral resolution due to the small size of the acoustic footprint. The seismograms were recorded in intervals of a few seconds and digitized with 40 kHz sampling frequency.

A detailed echosounder survey was carried out in the vicinity of ODP drill sites 689 and 690 on Maud Rise (Antarctica). The digital seismic profiles can be directly compared to the drilling results derived from studies of sediment samples and core logging. The synthetic seismograms, which were calculated from physical property and sedimentologic data and the corresponding seismic wavelet, show a perfect correlation to the lithologic changes between carbonaceous and biosiliceous sediments.

Biosiliceous sediments are found extremely homogenous and are associated with acoustically transparent intervals, whereas increasing carbonate content causes larger fluctuations in acoustic impedance. Carbonate rich intervals can be clearly identified from a high number of reflectors and high reflection energy. Major gradients in carbonate content appear as high amplitude reflectors and can be traced in seismic sections over long distances. By this approach an acoustostratigraphic interpretation can be derived for the upper 100 m of sediments covering the Cenozoic history of the Maud Rise from Eocene/Paleocene times. Six acoustostratigraphic units can be clearly distinguished on most digital echosounder profiles across Maud Rise representing changes in the dominance of carbonaceous and opaline sedimentary components.

The top unit I of Pleistocene age represents a pure foraminiferal ooze of several meters thickness overlying pure biosiliceous sediments of Late Miocene to Pliocene age (Unit II; 20-40 m). Unit III with a characteristic reflector series is composed of Middle to Late Miocene sediments with variable carbonate content (10-15 m). A short biosiliceous interval from Early to Middle Miocene (Unit IV; 3-6 m) overlies sediments of high carbonate content. An Oligocene/Miocene hiatus separates an undisturbed sedimentary series with subparallel reflectors (Unit V; >20 m) from undulating sediment structures below (Unit VI).

BORON ISOTOPE PALEOCEANOGRAPHY

A.J. Spivack (Scripps Institution of Oceanography, UCSD, La Jolla, CA, USA)

The B-11/B-10 ratio of sea water is approximately 40 per mil enriched relative to continental rocks. Although sea water is isotopically homogeneous, consideration of its geochemical behavior indicates that its isotopic composition may vary with time and that the sea water/carbonate fractionation factor may be a systematic function of pH. This suggests a number of applications of B in paleoceanography that rely on determining both the isotopic evolution of sea water, as well as variations in fractionation factors. Our initial work in this field has focussed on developing precise and accurate methodologies for the analysis of boron abundances and isotopic compositions in small foraminifera and pore fluid samples, and using these techniques for defining general trends in these samples over the past 40 My.

Isotopic compositions can be determined with a precision of 1.5 per mil by negative ion thermal ionization mass spectrometry on 0.2 milligrams of carbonate or 0.1 microliters of pore fluid. B/Ca ratios are determined by isotope dilution of both B and Ca on a single sample split, with a precision of 0.25%, eliminating the need for weighing samples.

Both fluid and foraminifera samples from ODP Hole 803D have been analyzed. Pore fluid concentrations, from the sea-water interface to basement are constant within 3%. Based on diffusion models, this data indicates that over the past approximately 20 My, sea-water B concentrations and isotopic compositions have been nearly constant, averaged over diffusive time scales (calculated to be approximately 9 my at 20 my).

Mixed species assemblages of the >150 micron fraction of foraminifera were picked, examined by SEM and rigorously cleaned prior to analysis. B concentrations increase from recent values of approximately 5 ppm to 7 ppm at approximately 16 my and reach a value of 10 ppm at approximately 40 my. In contrast, isotopic compositions are constant, 16 per mil, over the past 9 my. Between 16 my and 40 my isotopic compositions decrease by approximately 20 per mil.

DISTRIBUTION OF MODERN AND LAST GLACIAL MAXIMUM SEDIMENT FACIES IN THE EASTERN CENTRAL ARCTIC OCEAN

R. Stein (Alfred Wegener Institute, Bremerhaven, Germany), H. Grobe, M. Wahsner, and the ARCTIC ´91 Shipboard Scientific Party

During the POLARSTERN Expeditions ARK VIII/2 and ARK VIII/3 (ARCTIC ´91) , unique sediment material was recovered from the eastern Arctic Ocean basins and ridges/plateaus, i.e., the Nansen, Amundsen, and Makarov Basins, the Gakkel and Lomonosov Ridges, and the Morris Jesup and Yermak Plateaus, as well as from the Svalbard/Barents Sea continental margin. In this paper, we present results from a detailed sedimentological investigation of surface and surface-near sediments, including carbonate, organic carbon, clay mineral, quartz, feldspar, and grain-size data.

In the first phase of our study, we have concentrated on the modern situation, i.e., on distribution maps of the different parameters determined in surface sediments. The distribution of these parameters is controlled by different environmental processes (such as sea ice distribution, terrigenous sediment supply, oceanic currents, surface-water productivity, etc.), as well as bathymetry. For example, distribution maps of the amount and type of organic carbon reflect that (i) the organic matter in modern eastern Central Arctic Ocean sediments is mainly of terrigenous origin and (ii) in the area north of Svalbard some higher amounts of marine organic matter may indicate increased surface-water productivity controlled by the inflow of the warm Westspitsbergen Current into the Arctic Ocean.

In a second phase of our study, we plan to produce similar distribution maps of the same variables for the Last Glacial Maximum (LGM) time slice. First LGM records of the siliciclastic and biogenic sediment components are presented here for selected core profiles from different basins and ridges.

STABLE ISOTOPE STRATIGRAPHY AND ORGANIC CARBON ACCUMULATION IN THE LATE QUATERNARY CENTRAL ARCTIC OCEAN

R. Stein (Alfred Wegener Institute, Bremerhaven, Germany), C. Schubert, and the ARCTIC ´91 Shipboard Scientific Party

A high-resolution study including stable isotopes, amount and composition of organic carbon fractions as well as carbonate contents, was performed on undisturbed surface-near (0 to 40 cm) sediment sequences taken by multicorer in the Makarov, Amundsen, and Nansen Basins and the Lomonosov and Gakkel Ridges during the international ARCTIC ´91 Expedition.

Based on the oxygen stable isotope records measured on *N. pachyderma* sin., the sediment sequences represent the last ~10 to 30 ky, i.e., mainly isotope stages 1 and 2. Sedimentation rates vary between 1 and 1.6 cm/ky in the Stage 1 interval. In the Makarov Basin core, sedimentation rates may reach a value of higher than 2.5 cm/ky during Holocene times. During Stage 2, sedimentation rates are lower, varying between 0.5 and 1.4 cm/ky.

The glacial/interglacial shifts in $\delta^{18}O$ may exceed 2 ‰ indicating that, in addition to the glacial/interglacial global ice-volume signal, other mechanisms such as changes in temperature or, more probable, salinity must have effected the isotope records. According to the trend to lighter oxygen stable isotope values in our core profile, there seems to be a general decrease in salinity (i.e., increase in meltwater influence) from the Gakkel Ridge and Amundsen Basin to the Lomonosov Ridge and Makarov Basin.

The organic carbon data display distinct variations in amount and composition during the last about 30 ky, interpreted as changes in surface-water productivity and supply of terrigenous organic matter. Increased organic carbon contents, parallelled by increased carbonate contents as well as increased abundances of foraminifera, biogenic opal, and coccoliths in the uppermost part of the sequences, suggest increased Holocene surface-water productivity (in comparison to the upper Pleistocene). Based on first estimates for sediments from the Gakkel and Lomonosov Ridges, accumulation rates of total organic carbon reach values of about 5.5 mgC/cm^2/ky during Holocene and about 1.4 mgC/cm^2/ky during Last Glacial Maximum times.

PALEO-ECOLOGY OF BENTHIC FORAMINIFERA IN THE NORWEGIAN-GREENLAND SEA: THE PAST 600,000 YEARS

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Eleven long sediment cores from the Norwegian-Greenland Sea have been investigated on their benthic foraminiferal content. Oxygen isotopic stratigraphy was the basic method to date the cores with the help of biostratigraphic marker-horizons. 42 benthic foraminiferal species were found and 5 taxonomic groups were described. The most important species during the past 600,000 years are *Oridorsalis umbonatus* (REUSS), *Cibicidoides wuellerstorfi* (SCHWAGER), *Cassidulina teretis* TAPPAN, *Triloculina tricarinata* d'ORBIGNY and *Pyrgo rotalaria* LOEBLICH and TAPPAN. Stratigraphic useful layers are marked by *Siphotextularia rolshauseni* (PHLEGER and PARKER) (in Stage 2), *Pullenia bulloides* (d'ORBIGNY) (in Substage 5.1) and *Globocassidulina subglobosa* (BRADY) (in Substage 11.3). Interglacial conditions are well documented by high amounts of *C. wuellerstorfi*. The calculation of 'individual-accumulation-rates' (INDAR) shows three or four times higher foraminiferal productivity in interglacial periods than in glacial. Four high-productivity events were observed in INDAR results. These periods (located in substage 11.3, 9.3, 7.1 and 5.5.1) show a regional strongly reducing faunal content from southeastern parts of Norwegian-Greenland Sea with highest amounts to lower INDAR northern- and westernmost. The interpretation of fossil habitats shows a distinct dominance of suspension-feeding epifauna during interglacial periods. Glacial periods are dominated by detritivore epi-/endofaunal periods. These results have been connected with the recent bottom-current system, which is the transport mechanism of feed material for suspension-feeders. Horizontal currents can therefore be precluded during glacial times. This could be interpreted as indicator for the 'Thermohaline Circulation System' in interglacials.

QUATERNARY CALCAREOUS NANNOFOSSILS FROM THE NORTHERN SOUTH CHINA SEA AND THEIR STABLE ISOTOPE RECORD

X. Su (China Univ. of Geosciences, Beijing, China; GEOMAR, Kiel, Germany) and W.-Z. Lü

The cruise Sonne 49 in the South China Sea (1987) was carried out by BGR (Germany) and SIO, SOA (P.R.China). The calcareous nannofossils in two cores (KL41, KL37) obtained during the cruise have been studied. *Emiliania huxleyi* and *Gephyrocapsa* are the most abundant taxon in the nannofossil assemblage; other common species are *Calcidiscus leptoporus, Helicosphaera carteri, Syracosphaera pulchra, Umblicosphaera sibogae, Umbellosphaera* , etc.

Three Quaternary calcareous nannofossils zones were identified: a) *Emiliania huxleyi* Acme Zone, characterized by the dominance of *E. huxleyi* (accounting for 40-60% of all individual nannofossils in the assemblage); b) *E. huxleyi* Zone, the dominator of which is *Gephyrocapsa ericsonii* (50-80%); c) *Gephyrocapsa oceanica* Zone.

Nine oxygen isotope stages were recognized by analyzing stable isotopes of calcareous nannofossils (1-30 μm fraction) from core KL41, which indicate the paleotemperature fluctuations in the South China Sea during the glacial and interglacial periods since Middle Pleistocene. The first appearance of *E. huxleyi* in core KL41 occurs in isotope stage 8, suggesting an age of about 270 or 280 kyr.

However, some records of our study are different from that of other studies. The reversal of the dominance of *G. ericsonii* and *E. huxleyi* occurs between the isotope stage 5e and 6, just a little later than the last disappearance of foraminifera *G. ruber* pink in this area, and it was supposed that the dominance of *E. huxleyi* in the study area begins about 110-120 kyr ago, earlier than that of 73-85 kyr in other areas.

The $\delta^{18}O$ values of this record varies from +0.25 to -2.65 ‰ (PDB) and are "lighter" than that in the Caribbean Sea (Steinmetz and Andersen,1984), which may be caused by the existence of many "$\delta^{18}O$ lighter" species such as *C. leptoporus*, etc. (Dudley et al., 1986; 1989), or by "compositional variations" in samples analyzed (Paull and Thierstein, 1987). Otherwise, during isotope stage 5 "the highest peak" is 5a rather than 5e. It needs further study to understand those differences.

It was shown by this study that the stronger carbonate dissolution occurs during the warmer isotope stages.

PLIO-PLEISTOCENE PALAEOCEANOGRAPHY AND PRODUCTIVITY FLUCTUATIONS OF THE WESTERN EQUATORIAL INDIAN OCEAN

J.E. Swallow (Institute of Oceanographic Sciences, Deacon Lab, Wormley, Godalming, Surrey, UK), B.M. Funnell, and T.D. Jickells

A 7.5m section of Ocean Drilling Program Hole 709C was analyzed, representing 1.37 - 2.28 Ma. The temporal sampling interval was 5.12 ky. The relative abundance of each planktonic foraminifer species was calculated, and the F20 transfer function was then applied to these data. Mg/Ca and Sr/Ca atomic ratios were also determined in *Globorotalia menardii* and *Globigerinoides sacculifer.*

Temporal fluctuations observed in the quantitative and geochemical data were correlated with the established $\delta^{18}O$ record for ODP 709C using spectral (time series) analysis. This identified significant orbital frequencies of oscillation (obliquity and precession) and quantified the phase relationships of each parameter.

A palaeoceanographic scenario was constructed for times of low and high $\delta^{18}O$. "Interglacial" periods appear to be associated with stronger meridional (monsoonal) winds, which promoted the development of a deep surface mixed layer in the equatorial Indian Ocean. The surface waters were relatively warm, favouring increased magnesium incorporation in foraminiferal calcite. Surface water productivity was relatively low due to a restricted nutrient supply.

Stronger zonal (trade) winds are inferred during "glacial" periods. These enhanced equatorial divergence upwelling, and the consequently higher rate of nutrient transport to the upper ocean promoted strontium incorporation in foraminiferal calcite. Cooler surface water temperatures are inferred.

COMPARISONS BETWEEN THE OXYGEN ISOTOPIC COMPOSITION OF PORE WATER AND *GLOBERGINOIDES RUBER* IN SEDIMENTS FROM HOLE 817C, LEG 133

P.K. Swart (Stable Isotope Lab, MGG/RSMAS,Univ. of Miami, FL, USA)

The oxygen isotopic composition of pore waters squeezed from sediments in Hole 817C covaries with the oxygen isotopic composition of *Globerginoides ruber* below 8 mbsf. The magnitude of the variation in the pore water $\delta^{18}O$ is approximately 30% of the variation in the foraminifera. Overall the $\delta^{18}O$ of the pore waters increases down-core, a trend which is also present in the concentration. The variations in the $\delta^{18}O$ of pore waters may be the result of either of two phenomenon. First, they may reflect original variations in the waters the magnitude of which has been subsequently reduced by processes of diffusion. Second, they may reflect processes of carbonate recrystallization. At the moment we do not have sufficient data to ascertain which process is responsible, although the correlation between the Cl^- and the $\delta^{18}O$ data suggests that the values reflect the original composition modified by diffusion.

PROCESSES RESPONSIBLE FOR EXPORT PRODUCTIONS OF DIATIOMS, SILICOFLAGELLATES AND RADIOLARIANS IN THE PELAGIC REALMS

K. Takahashi (Hokkaido Tokai University, Sapporo, Japan; WHOI, Woods Hole, MA, USA)

Several major factors governing the sinking of the siliceous planktonic organisms will be discussed. In particular, the primary factor determining the export is production in the upper layers which is governed by climatic (physico-chemical) variables in many cases. Second, predation and mortality are important in transforming the biocoenioses into sidocoenosis, sinking assemblage (Takahashi, submitted 1991). Third, the major factor determining changes between the export production to fluxes in the deep sea are dissolution of siliceous skeletons. The dissolution depends not only on pH, temperature

and dissolved silicon concentration in ambient water, but also largely on mode of transport of the skeletons (i.e., discrete or marine snow). Thus, the thermodynamics becomes less important for dissolution of the sidocoenosis. This is called "sidocoenosis preservation hypothesis," and there exists many pieces of evidence suggesting insignificant dissolution of the siliceous skeletons enroute to the sea floor, except for phaeodarian radiolarians, at least below several hundred meters depth in the pelagic environments (Milliman and Takahashi, in press). Finally, the sidocoenosis will be significantly altered in their composition due to long exposure time to water and subsequent dissolution at the sea floor where they become thanatocoenosis. The extent of the fossil preservation on the sea floor and in the sediments largely depends on extent of siliceous plankton fluxes from the upper water.

ON PLEISTOCENE UNDER-GLACIER FLOWS OF THAWING WATERS OF THE LAST GLACIATION IN THE ARCTIC SEAS SEDIMENTATION

G.Tarasov (Murmansk Marine Biological Institute, Academy of Sciences, Russia)

Generalization and analysis of ground samples, marine drilling and continuous seismic profiling data for the last decade, as well as various glaciological exploration data make it possible to study the Quaternary sedimentogenesis evolution in the Arctic seas in a different way and, above all, in close interrelation with sheet Pleistocene glaciers. Taking into account the well-known conception that the vast areas of North America and Northern Europe, the Arctic Islands and archipelagoes had been under cover of glaciers in the Quaternary, and that the latter in their turn were rafting onto the adjacent shelf in the period of the maximum phase in the evolution, it should be noted that, in effect, erosional and cumulative glacier activities, marine periglacial events, and processes related to them, were significant in scale. Final formation of bottom relief and bottom sediments in the Arctic shelf took place at the end of Pleistocene in conditions of complicated manifestation of sedimental and relief-forming processes related to deglaciation of the last glaciers. The under-glacier flows of thawing waters are thought to be of great importance in the main eroding and accumulating factoring Pleistocene sedimentogenesis. The under-glacier flow channels are well-distinguished on the seismic lines shot on the Arctic shelf in North America and Eurasia. The observed large washouts in the shelf sediments can be referred to erosional configurations formed by the under-glacier flows of thawing waters in the early and middle Pleistocene which were filled up by glacier sediments at the end of deglaciation. Under-glacier tunnels are known to extend underneath and inside the glaciers for hundreds of kilometers; they form a forked network of corridors and branches. Being under high hydrostatic pressure caused by the glacier thickness, the flows of under-glacier thawing waters, in their turn, were eroding the glacier bed forming the channel system. The flow proper which was constantly replenished by thawing waters and mineral fractions from erosion of rocks of the under-glacier bed, had high speed in the under glacier exit, a high-density and a high content of terrigenous sedimentary rocks. During the ice period a large volume of sediments was carried out into the Arctic seas, the fine-grained constituents of which are encountered even on the cross-sections of bottom sediments in the deep-water basins of the central Arctic.

CLIMATIC AND PALEOCEANOGRAPHIC CHANGES DURING THE LATE QUATERNARY IN THE WESTERN GULF OF LIONS (NORTHWESTERN MEDITERRANEAN): THE PALYNOLOGICAL RECORD

J. Targarona (Lab of Paleobotany and Palynology,Univ. of Utrecht, The Netherlands), M. Canals, A. Calafat, K. Zonneveld, and G. Versteegh

The Gulf of Lions is characterized for having a 70km-wide shelf, incised by canyons with NW-SE to N-S general trends. Main hydrographic features of the Gulf of Lions, include a superficial low-salinity wedge from the Rhône River in the NE and the NE-SW flow of the Liguro-Provençal Current. Two 4m-long Kullemberg cores drilled in western Gulf of Lions are being studied from a palynological point of view. In this contribution we show the provisional results of the analysis of one core drilled in the interfluve separating the Cap the Creus and Lacaze-Dutiers canyons, at a depth of 1,200m.

On the basis of compositional shifts in the dinoflagellate assemblages, the Würm IV, Bölling/Alleröd, Younger Dryas and Holocene stages were recognized.

The cool stages Würm IV and Younger Dryas show not only an increase in the cool-warm dinoflagellate ratio but also high relative abundances of *Protoperidinioid* dinoflagellate cysts indicating an increased productivity. For the Bölling/Alleröd and Holocene stages , a less productive, open marine environment is indicated by high relative abundances of *Impagidinium spp.* Furthermore, the down-core distribution of *Impagidinium spp.,* indicators of oceanic environment, shows two transgressive moments with maxima at 0.75m and 2.60m core depth. The upwards increase in the percentages of spores and angiosperm pollen grains is interpreted as a reflection of the land vegetation recovery after the glacial times and highlights the importance of the Liguro-Provençal current in the transport of river organic matter from the Rhône River in the NE.

SLOW MOTION OF OCEANIZATION IN THE NORTHERN ETHIOPIAN RIFT SYSTEM

A. Tessema (Ethiopian Institute of Geological Surveys, Addis Ababa, Ethiopia)

The Ethiopian Rift is part of the East African Rift, which is the result of uplifting of the Horn of Africa during Upper Miocene. This was followed by fracturing of the lithosphere, which has resulted in rifting and oceanization of the crust. There is a slow motion of oceanization of the northern tip of the East African rift, particularly the region which is situated in northern Ethiopia.

The present study is dealing with investigation of the rate of motion of oceanization beneath the northern Ethiopian rift. The geodynamic problem of this region has been studied since l960 by using different geophysical methods. This paper gives a synoptic view of the results of interpretation of regional gravity data over the ongoing oceanic crust beneath the Ethiopian rift. It summarizes the results of interpretation of regional gravity data collected up to l99l. A total of 6,850 gravity points were used to compile the map with l:8,000,000 scale.

The northern Ethiopian rift is characterized by high-amplitude of bouguer gravity which shows characteristics of oceanic crust. The amplitude changes along NE-SW direction which is aligned to the axis of the main East African rift. The nature of gravity anomaly shows progression of oceanic crust towards a south-west direction. The present work of the paleomagnetic study of this region revealed that the Red Sea oceanic crust is expanding in the south-west

direction which is along the axis of the East African Rift System. This conclusion is drawn from inspection of regional gravity and magnetic maps of the region.

OCEAN SEDIMENT FLUXES: SPATIAL AND TEMPORAL VARIABILITY IN THE ATLANTIC OCEAN

J. Thiede (GEOMAR, Kiel, Germany), W. Brückmann, W. Brenner, J. Mienert, T.C.W. Wolf, A. Dettmer, and K.U. Schmidt

DSDP and ODP have provided a data base to quantify sediment fluxes into the ocean basins during the Late Mesozoic and the Cenozoic. As part of a major project to study the history of pelagic sedimentation in the world ocean we are concentrating presently on the Late Cenozoic Atlantic Ocean. Due to its late plate tectonic history and the opening of gateways connecting the Arctic and the Antarctic, today it is principally different from the Indian and Pacific oceans. Deep-water renewal occurs both in the Greenland Sea and in the Atlantic sector of the Southern Ocean due to the down-welling of cold, oxygen-rich waters causing an intense stratification of the deep intervals of the oceanic water column, whereas the Atlantic Ocean has been disconnected from the circum-equatorial current system due to the collision of the African and Eurasian plates and due to the construction of the middle American land bridge during the Middle and Late Cenozoic. The distributional patterns of Late Cenozoic sediment fluxes plotted into a carefully reconstructed palinspastic framework of the paleophysiography of the Atlantic reflect the major elements of the surface-water circulation, as well as the source areas for the lateral advection of the terrigenous components. The peculiar mode of Atlantic deep-water renewal and circulation can also be deduced from the temporal and spatial distribution of hiatuses in the various sediment columns. A major effort is required to homogenize the stratigraphic data base, which is accomplished by establishing an artificial holo-stratigraphy through stacking of all potential bio-events. Sediment compositions and physical properties are compiled from the DSDP/ODP data bases with minor corrections. The results of the project are illustrated in a series of palinspastic maps illustrating the mass-balanced distribution of sediment fluxes of biogenic and terrigenous sediment components for time slices of 1 - 5 mio. y. in duration. They allow the establishment of descriptive paleoceanographic models for the Late Cenozoic Atlantic Ocean.

THE MODERN ATMOSPHERIC AND OCEANIC SURFACE CIRCULATION AND ITS RECORD IN SEDIMENTS OF THE SOUTHWEST PACIFIC OCEAN

J. Thiede (GEOMAR, Kiel, Germany), S. Nees, and H. Schulz

Due to its shallow topography, the seafloor east of Australia is one of the few extensive areas of the Pacific Ocean where biogenous calcareous components are widely preserved. 180 surface sediment samples were investigated for their planktic foraminiferal (> 149 µm) and terrigenous sediment components. These data were used to trace atmospheric and oceanic circulation patterns and to develop, with multivariate statistical methods, an equation for the calculation of sea-surface temperatures and salinities. The pattern of the percentage distribution of quartz can be related to modern wind regimes. In recent sediments the quartz content is a distinct

tracer for the atmospheric circulation in the region east of Australia. A large lobe of high quartz concentrations extends eastwards from the coastline. This is related to major wind and storm tracks acting as transport mechanism across the southern part of the landmass. The concentration of biogenous opal is related to productivity of surface-water masses. The abundance of opaline components in the sediments decreases slightly towards the west. South of the highly productive tropical water masses they are strongly decreasing. The distribution patterns of major species of planktic foraminifers reflect different surface-water masses. The impact of subtropical-tropical water masses is indicated by high abundances of *G. ruber* and *G. sacculifer*. High percentages of *G. bulloides*, *G. inflata* and *N. pachyderma* reveal the influence of subpolar-polar waters. Q-mode factor analysis of the planktic foraminiferal counts (63 core tops) allows definition of characteristical foraminiferal assemblages. The four most important factors explain 95.5% ot the total variance. Factor 1 (66%) is dominated by the tropical-subtropical species *G. sacculifer* and *G. ruber*. The transitional to subpolar species *G. inflata* is important in factor 2 (12%). The temperate cool factor 3 (13%) is composed of *G. quinqueloba* and *G. glutinata*. Factor 4 explains 3% of the total variance and is represented by various species. It is assigned to high productive coastal waters off the Australian continental margin. The computed equation allows one to evaluate sea-surface temperatures and salinities. The results were correlated to data adapted from the literature and correspond with 95% (temperatures) and 77% (salinities).

THE PALEOCENE BENTHIC FORAMINIFERAL EXTINCTION

E. Thomas (Geology and Geophysics, Yale University, New Haven, CT, USA) and N.J. Shackleton

Deep-sea benthic foraminifera underwent one global mass extinction during the last 75Ma, in the latest Paleocene, which occurred rapidly (10^4 yrs. or less), and was coeval with large, transient excursions to lighter carbon and oxygen isotopic values in benthic and planktonic foraminifers. Isotopic excursions have been observed over depths between 1000 and 3500m in Atlantic, Pacific and Indian Oceans. At high latitudes (southern-most Atlantic and Indian Oceans) post-extinction faunas were dominated by small, thin-walled biserial forms (e.g., *Tappanina selmensis*), from 1100 - 1900m paleo-depth. *Nuttallides truempyi* was absent for several hundred thousand years after the extinction. At sites on Walvis Ridge (mid-latitude, southern Atlantic Ocean, 1600-3400m paleodepth) post-extinction faunas were dominated by *N. truempyi*, and, especially at greater depth, abysaminids; all specimens were small and thin-walled. On Walvis Ridge and in the Indian Ocean the extinction occurs a few cm above the base of a clay layer ($CaCO_3$ <35%) within the calcareous oozes; at Maud Rise $CaCO_3$ dropped from ±90 to 65%. During the late Paleocene there were global high turnover rates in planktonic organisms, and overall low productivity. The dominance of biserial forms just after the extinction argues against a drop in surface-water productivity at high latitudes as the cause of the extinction; these faunas suggest (local) high productivity and/or low oxygen levels in deep waters. The synchroneity of the extinction and large, transient isotopic changes suggest that extinction was synchronous worldwide and occured at a time of major changes in climate and the functioning of the carbon cycle. We speculate that temporary short-term, extremely high rates of CO_2 emissions from North Atlantic flood basalt activity caused high-latitude warming, and thus a major decrease in the contribution of high-latitude sources to the global deep water masses, with concominant changes in deep-water physiochemical parametres as well as loci of upwelling and high productivity. Changes in deep-water character, as well as local changes in productivity then caused the extinction.

NORTHEASTERN ATLANTIC BENTHIC FORAMINIFERA DURING THE LAST 30,000 YEARS

E. Thomas (Geology and Geophysics, Yale University, New Haven, CT, USA), L. Booth, M. Maslin, and N.J. Shackleton

Benthic foraminiferal faunas over the last 30kyr were studied in the >63µm size fraction in samples from BOFS cores 5k and 14k (50°41.3'N, 21° 51,9'W, 3547m and 58°37,2'N, 19°26,2'W, 1756m: time resolution several 10^2 years). The timing of deglaciation was estimated using the oxygen isotopic record of *Neogloboquadrina pachyderma* (5k), and of *Globigerina bulloides*, in combination with the relative abundance of *N. pachyderma* (s) (14k). At both sites *Pullenia* species were common during the glacial; at 5k assemblages became less diverse (20-30 species), and dominated by *Epistominella exigua* and *Eilohedra weddellensis* after deglaciation. Absolute abundances of *Pullenia* spp. did not change significantly. The increase in relative abundance of *E. exigua* and *E. weddellensis* parallels the decrease in relative abundance of the planktonic foraminifer *Neogloboquadrina pachyderma* (s), a polar water indicator. We therefore conclude that this increase in relative abundance was probably related to changes in surface-water conditions (highly increased input of phytodetritus) after deglaciation, and not to changes in bottom water conditions at the site of 5k. The faunas at 14k did not show major faunal change at the timing of deglaciation. We thus have no evidence that decreased production of North Atlantic Deep Water during the last glacial had an effect on benthic foraminifera in the eastern North Atlantic basin at depths of 1756 and 3547m. There was no faunal change during the Younger Dryas, suggesting that circulation did return to fully glacial conditions at that time. Faunas at 5k varied considerably during the glacial; at 21-22 kyr they were dominated by the arctic species *Stetsonia horvathi* s.l. The benthic event was coeval with Heinrich event 2, a peak in lithic concentration and magnetic susceptibility and a short excursion to lighter values of $\delta^{18}O$ of *N. pachyderma* (s). There were no significant changes in planktonic foraminiferal faunal composition. There might have been a short period of excessive meltwater formation, possibly resulting in an upset of deep-water formational processes.

SEASONAL SEDIMENT FLUXES AND VARVE FORMATION IN THE GULF OF CALIFORNIA

R. Thunell (Dept. of Geological Sciences, Univ. of South Carolina, Columbia, USA), C. Pride, E. Tappa, F. Muller-Karger, C. Sancetta, and D. Murray

A time-series sediment trapping program is currently being carried out in the Gulf of California. Two of the objectives of this study are to document seasonal variability in the flux of various sediment components (biogenic and non-biogenic) to the seafloor, and to evaluate previously proposed models for varve formation in the Gulf. The organic carbon, carbonate, opal and terrigenous sediment flux patterns for the year-long period from February 1991

to February 1992 display a great deal of temporal variability, with some basic seasonal trends common to all four records. First, the spring (March through first half of June 1991) was a time of overall low sediment flux, for both biogenic and non-biogenic sediments. This observation is somewhat surprising since this is the time of year when upwelling is usually most intense and surface productivity highest. Multi-year, time series records of CZCS data consistently show that the spring is the time of highest pigment concentrations in the Gulf. As a result, it was anticipated that opal flux would be highest during the spring but this was not the case. The two main contributors to the opal flux, diatoms and silicoflagellates, have low to moderate fluxes during the spring. Biogenic and non-biogenic sediment fluxes tend to be high from summer through early winter, with terrigenous material predominating.

Based on these observations, we conclude that the light sediment laminae are deposited during the spring. Although this is a time of overall low fluxes, the sediments are comprised mostly of biogenic material (particularly opal) and thus are not highly diluted by terrigenous material. The light laminae do not represent the time of highest silica production during the year. In contrast, it appears that the dark laminae represent deposition over a prolonged period from summer to early winter. Even though opal fluxes tend to be high during this period, it is greatly diluted by even higher fluxes of lithogenic material. It is conceivable that a light layer could be formed during the winter if opal fluxes remained high and lithogenic fluxes decreased significantly.

RADIOLARIAN MASS ABUNDANCE/HIGH DIVERSITY, STABLE ISOTOPE VARIATIONS, BLACK SHALE SEDIMENTATION, AND SEA LEVEL CHANGES IN THE MID-CRETACEOUS - AN INTEGRATED APPROACH

J. Thurow (Ruhr-Universität, Bochum, Germany), J. Erbacher, and H. Strauss

There is a striking correlation between radiolarian mass abundance/ high diversity/taxonomic turnover, positive $\delta^{13}C/\delta^{13}C_{org}$ excursions, black shale sedimentation, and sea-level changes in the pelagic realm during mid-Cretaceous events (Aptian-Turonian).

Radiolarian productivity is controlled by either the silica content of the seawater and/or nutrient supply. Cretaceous seawater in general was undersaturated with respect to SiO_2, so nutrients are the controlling factor for radiolarian abundance and diversity. Thus, and because radiolarians are not confined to special lithologies, they indicate high surface productivity. Increased flux of radiolaria reduces the importance of dissolution and skeletons are also preserved in lithologies, e.g., limestone, generally unsuitable for their preservation.

Positive carbon isotope excursions can be regarded as times of accelerated carbon cycling coupled with increased burial rates of C_{org} causing black shale sedimentation.

Comparing the factors above with the eustatic record, it is evident that they not only correlate with the 2nd order transgressive trends of the Cretaceous, but also with 3rd order transgressive systems tracts.

Overprinted on the 2nd order transgressive trend wich leads to progressive leaching of nutrients from soil of flooded lowlands, are 5th order cycles. They may result from glacial eustacy or from changes in intraplate stress (due to fast global spreading), giving rise to rythmic nutrient flux to the oceanic reservoir.

With the attainment of the modern deep water circulation system (north-south instead of east-west) with its oxygenated deep-water masses and the stabilisation of the high sealevel in the Upper Cretaceous (post middle Turonian), the nutrient reservoir becomes exhausted and black shale-sedimentation as well as high productivity of radiolaria ceased.

Mass abundances of radiolaria does not occur until Lower Campanian (LCE - Lower Campanian Event), locally coinciding with a positive carbon isotope excursion, but without any organic-rich sediments deposited on a global scale.

ASTRONOMIC TUNING OF HIGH-RESOLUTION BENTHIC $\delta^{18}O$ RECORDS FROM ODP-SITES 658 AND 659 FOR THE LAST 5 MILLION YEARS VS. NON-LINEAR CLIMATIC DYNAMICS

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High-resolution dust flux and benthic oxygen isotope records from ODP-Sites 658 and 659 were calibrated to orbital forcing using phase relations between the $\delta^{18}O$ isotope cycles and the corresponding cycles of orbital precessionand obliquity. For the last 2.5 Ma, this age model is consistent with the astronomical age model of Shackleton et al. (1991).

For the early Pliocene we extended the astronomically calibrated oxygen isotope time scales back to 5 Ma. We based our tuning on two proxy records from Site 659: (1) The dust flux record, which is indicative of aridity fluctuations in the Sahel zone, shows dominant precession periods near 19 and 23 ka from 5.0 - 3.3 Ma. Later, between 3.3 -2.7 Ma, these cycles shift to a dominant 41ka cycle parallel to the gradual climatic deterioration. Correspondingly, the variance at the precessional band decreases until the end of the Pliocene. (2) The benthic $\delta^{18}O$-record that serves as a measure of global ice volume and bottom water temperature confirms the dominance of the 41 ka rhythm of orbital obliquity. By tuning both the dust flux record to orbital precession and the benthic $\delta^{18}O$-record to orbital obliquity we arrived at a uniform time scale which suggests that the Pliocene lasted about 500ka longer than commonly assumed, i.e., back to about 5.3 Ma.

In order to understand the residual variance in the frequency domain, which remains unexplained by cross-spectral analysis, the total variance of the records is tested in a multi-dimensional phase space to specify mechanisms of non-linear climatic forcing.

SEASONAL FLUX PATTERNS OF PLANKTONIC DIATOMS AND SILICOFLAGELLATES IN THE GUINEA BASIN

U.F. Treppke (Universität Bremen, Germany) and C.B. Lange

The diatom and silicoflagellate content of sediment trap samples from various depths collected close to the equator in the Guinea Basin from March 1989 through March 1990 was determined. The results were compared with biogenic opal and total fluxes (Wefer and Fischer; Deep-Sea Res., in prep.).

Fluxes in the study area were related to seasonal shifts of the Inter Tropical Convergence Zone (ITCZ) and associated variations of the trade wind system. At the northern Guinea Basin site (GBN3), highest total fluxes occured during August and September, a period characterized by the strongest southern trades and the northernmost displacement of the ITCZ. At the southern site in the central Guinea Basin (GBZ4), total flux was highest during March to May, after the ITCZ had reached its southernmost position and during the maximum influence of the northern trades.

Flux pattern of diatoms and silicoflagellates at GBN3 showed highest values in March and April and a second peak in August and September. The spring flux showed a strong coastal influence, the summer peak was related to upwelling. That summer upwelling didn't affect site GBZ4 as much as GBN3, so that at this site high fluxes were restricted to March-May.

A total of approximately 200 species were identified. *Nitzschia bicapitata* was an important contributor to the diatom flux at both sites. The occurrence of *Fragilariopsis kerguelensis* in the GBZ4 trap in July marked the northernmost displacement of the subantarctic species by the Benguela Current.

At GBN3, the diatom and silicoflagellate flux of the lower trap followed the flux pattern of the upper trap with some smoothing and a time lag of about 2 months.

Flux values calculated from sediments indicate a loss of about three orders of magnitude for both the diatoms and the silicoflagellates.

RECENT SURFACE WATER PLANKTONIC FORAMINIFERA OFF SW AFRICA, ANGOLA BASIN

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Counts of planktonic foraminifera, collected from the surface water and vertical plankton net (VPN) in the eastern equatorial and south Atlantic Ocean during October and November 1989, yielded 5 clusters which reflect the hydrographical features of the region.
Based on the nature of the species, the clusters are mainly determined by temperature, salinity and productivity of the surface waters.

In the upper part of the water column, there is a gradual change from *Globigerinoides ruber* pink to *Globigerinoides sacculifer* dominated fauna pointing to an increase in salinity and thickness of the mixed layer, while the fertility decreases from the Zaire River to the west.

From the Zaire River to the south, the variation in composition of the foraminiferal fauna assemblage reflects a more pulsated change in hydrography towards a colder and more nutrient rich surface waters, reflected by species of clusters 2 (*Neogloboquadrina pachyderma*). The main changes occur at the Angola-Benguela Front (15-17°S), a region dominated by species of cluster 5 (*Globigerina bulloides*) on one hand and secondly cluster 4 (*Neogloboquadrina dutertrei*) on the other hand, reflecting the opposing relation between the influence of the northward flowing, cold and nutrient rich Benguela Current and the southward flowing, warm and highly saline, South Equatorial Counter Current.

In the Walvis Bay region (23°S), the presence of the two coiling types of *N. pachyderma* can be explained by a year-round presence of dextrally coiled specimens and an activity of sinistrally coiled specimens during upwelling seasons.

The difference in distribution of sinistrally and dextrally coiling *N. pachyderma* cannot be attributed to temperature difference alone, as generally believed . Here, the change in coiling direction seems to be largely generated by phytoplankton productivity, since the occurrence of sinistrally coiled *N. pachyderma* off Walvis Bay is related to high phosphate concentrations.

QUATERNARY PALEOCEANOGRAPHY OF AN ACTIVE BACK-ARC BASIN, OKINAWA TROUGH AND ITS ENVIRONS

H. Ujiie (Dept. of Marine Sciences, Univ. of the Ryukyus, Okinawa, Japan)

The Ryukyu Island Arc extends ≈1200 km from lat.24°N to 31°N and bounds the western margin of the North Pacific Ocean. The Okinawa Trough separates the Arc from the East China Sea shelf. After turning north from the north equatorial current, the Kuroshio crosses the southermost part of the arc, flows northeastward along the boundary between the trough and shelf, and runs across the northern arc.

During the Late Quaternary, however, this western boundary current and its counter currents have greatly changed. The argument is based on analysis of 11 piston cores and on reviewing knowledge of land-based and submarine geologies.

Stable oxygen isotope stratigraphy and technochronology of cores from the trench slope region of the arc and the trough margin suggest that the southern entrance of the Kuroshio has been closed by an island-bridge during Emiliani Stage 2, whereas it was not closed during the last interglacial episode. The island-bridge running from Taiwan to NE of Ishigaki Island has been broken by the recently activated spreading of the trough. This movement has occurred with periodicity of ≈1500 years after ≈10ka, according to a calculation using "Terminations I_A and I_B" and their ^{14}C ages recognized in two turbidite cores. Oxygen isotope variations of the trough region cores include spikes of fresh water from the continent or show abnormal modes during the closing period of the southern entrance, while those after its opening indicate normal deglaciation modes towards the Recent.

CENOZOIC PALEOENVIRONMENT CHANGES ACCORDING TO CALCAREOUS NANNOPLANKTON

M. Ushakova (P.P. Shirshov Institute of Oceanology, Academy of Sciences, Moscow, Russia)

Ecological data from calcareous nannoplankton are used for the ocean and sea paleoenvironment reconstructions. The *coccolithothophorida phytocoenosis* are shown to be close in quantitative and qualities characteristic to modern sedimentation nannoplankton complexes, though there are a number of rare thin-wall species not met practically in sediments. The species diversity and nannoplankton quantity in the open ocean depend on climatic and circumcontinental zonality. The same indices in the seas mostly depend on the degree of the isolation. In the oceans (normal salinity - 35-36‰) there are about 200 species; in Quaternary bottom sediments there are 50, in the Mediterranean Sea (S=37-39‰) there are 75 and 10, correspondingly, in the Black Sea (S=16-18‰) there are 45 and 23, in the Caspian Sea the nannoplankton is not found, and in the Red Sea (S=40‰) - 9 species in the sediments. Therefore, the poorest complex is in the Black Sea. In the Pleistocene some layers were only enriched by one of three dominant species (*Emiliana huxleyi, Braarudosphaera bigelowie*). Therefore, the species diversity index and their dominance degree in the sea sediments indicate paleosalinity fluctuations that depend on the water exchange with the open ocean.

The nannoplankton distribution in the sea and ocean-bottom sediments also reflect the water temperature fluctuations. For the Cenozoic there are the following indices of cold waters: *Coccolitus pelagicus* and *genus Chiasmolithus* and of warm waters - *genus Discoaster*. We created the paleotemperature curve on quantitative changes of *Coccolithus pelagicus* for the Neogene tropical Pacific. We determined that there were seven larger relatively cold snap stages which lasted 1.0-1.5 million years. The results of these investigations furnish great possibilities for further paleoclimatic synthesis.

NEOGENE-QUATERNARY CLIMATIC CHANGES IN THE EAST-TROPICAL PACIFIC

M. Ushakova (P.P. Shirshov Institute of Oceanology, Academy of Sciences, Moscow, Russia) and N. Blyum

The data of the paleoclimatic analysis on nannoplankton, on planktonic foraminifera and on oxygen isotopic results have been compared. Climatic changes are studied in two time scales: several tens of 100 ky for the Quaternary and 0.5-2.0 m.y. for the Neogene. In the region during the last 1.25 m.y., six cold-waters epochs of the glacier rank were identified from foraminifera (five from coccolithophorids), with determination of the age of the epochs. From the Eopleistocene to the Middle Pleistocene there is a tendency to cooling, but since that time to Recent it has turned to warming. Seven large stages of relative cooling lasting 1.0-1.5 m.y. have been established in the Neogene. There is a marked trend in the region of climate developing to warming from the beginning of the Miocene to Early Pliocene and to cooling from the end of the Early Pliocene to the middle of the Pleistocene. It has been found that the long-term variations of climate and changes in the trend during the Neogene were caused by tectonic movements (the appearance of the Drake Passage and of the Panama Isthmus) which brought about reformation of oceanic circulation. Climatic variations in the Quaternary were associated with the development of the glaciation in the Northern Hemisphere which changed the intensity of the Trade Wind currents and equatorial upwellings.

EVIDENCE FROM Cd/Ca RATIOS IN BENTHIC AND PLANKTONIC FORAMINIFERA FOR VARIATIONS IN UPWELLING INTENSITY IN THE CALIFORNIA CURRENT

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Dissolved Cd enrichments in California coastal waters are the result of upwelling superimposed on the phosphate-like vertical distribution of Cd in the ocean. We show that the Cd/Ca ratio of a shallow water benthic foraminifer, *Elphidiella hannai*, is a function of ambient Cd/Ca at the time of shell formation with Kd= (Cd/Ca)sw/(Cd/Ca) shell ~ 5.3. A Cd/Ca decrease from 360 to 280 nmol/mol for this species in a sediment core from San Francisco Bay suggests that upwelling in adjacent coastal waters decreased significantly over the past 4.000 years.

Variability of upwelling in the region was also inferred over longer time scales from the Cd content of planktonic *Neogloboquadrina pachyderma* in a sediment core from the California slope. Cd/Ca ratios of this species are relatively constant at 40 nmol/mol from the last glacial maximum to 10,000 years before present, then increase rapidly to a value of 120 nmol/mol in the upper 1 m of the core. The later value is comparable to Cd/Ca in *N. pachyderma*

collected by sediment traps outside Monterey Bay. The record, therefore, suggests that upwelling in the California Current was significantly weaker between 20,000 and 10,000 years BP than today.

The pattern of upwelling off California inferred from the Cd content of both planktonic and benthic foraminifera is consistent with COHMAP predictions (Science **241**, 1043-1052, 1988) of changes in wind strength and direction in the region during the last deglaciation.

PLIOCENE SAPROEL FORMATION IN THE EASTERN MEDITERRANEAN: PRODUCTIVITY, DISSOLUTION, AND DILUTION

B. van Os (Institute of Earth Sciences, Univ. of Utrecht, The Netherlands)

The conspicuous rhythmic bedding in the lower Pliocene Trubi formation on Sicily consists of quadripartite depositional sequences. These sequences display a distinct white-grey-white-beige color layering with the grey and beige marls being less indurated and $CaCO_3$-poor. In addition, the grey layers are enriched in C_{org} (1-1.5%). In the basal part of the overlying Monte Narbone Fm, brownish colored, often well laminated layers occur, enriched in C_{org} (usually termed sapropels). These are intercalated in the grey layers of quadripartite cycles.

A recent model relates white-colored, carbonate-rich layers of the carbonate cycles in the Trubi to highly productive surface-water conditions, caused by intensified upwelling. On the other hand, increased continental runoff in combination with enhanced primary production is the most widely accepted model for (Pleistocene) sapropel formation.

To solve this contradiction, we have carried out a multidisciplinary study of sapropel containing a $CaCO_3$ cycle by measuring Ba, organic carbon, $\delta^{13}C_{org}$, Ca, Al, Ti, V, Fe, S, shell flux, $\delta^{13}C$ and $\delta^{18}O$ of planktonic foraminifers taxa.

On the basis of preliminary results, we conclude that at times of sapropel formation, primary non-carbonate production (diatoms and algae) was high, comparable to conditions prevailing in modern upwelling areas. In addition, the $CaCO_3$ content has been lowered by $CaCO_3$ dissolution at the sediment-water interface as a consequence of the higher C_{org} decomposition. During the deposition of the white layers, carbonate production was high, suggesting a lower level of primary productivity and nutrient supply than during the formation of the grey marls and sapropels. The beige layer represents a period of low primary productivity and low carbonate production.

SEDIMENT CHEMISTRY AND BENTHIC FORAMINIFERA IN SALT MARSH SEQUENCES AS AN INDICATOR OF RELATIVE SEA-LEVEL RISE OVER THE LAST 1,500 YEARS

J.C. Varekamp (Dept. of Earth and Environmental Sciences, Wesleyan Univ., Middletown, CT, USA) and E. Thomas

We developed a combined chemical/faunal approach to characterize depositional sub-environments in salt marsh sequences. The composition of benthic foraminiferal assemblages and the iron and sulfur abundances in peats are used to quantify shifts in the position of mean sea level with respect to a chosen datum level (mean high water) in marsh sequences over the last 1500 years. Studies in Clinton (CT, USA) provide a relative sea-level rise curve, with age control from AMS ^{14}C dating and the onset of anthropogenetic metal pollution. Local changes in tidal range might have contributed to the apparent changes in rate of relative sea level. The curve shows a strong increase in the rate of relative sea-level rise during modern global warming (MGW, since AD 1850), but not during Little Climate Optimum period in western Europe (LCO, AD 1000-1300). There was only a very slow rise of sea level during the Little Ice Age (LIA, AD 1400-1700). Changes from slow to fast rates of relative sea-level rise apparently occurred about AD 1200-1450, a period of cooling in Western Europe, but of rapid warming at higher latitudes (Scandinavia).

We observe a general correlation between the rate of relative sea-level rise in Clinton and global climatic trends (MGW and LIA), but local temperature records of the high latitudes show a better correlation with the sea-level rise record than mid-latitudinal records. High- latitudinal climate shifts may induce a stronger signal in ice melting and therefore more directly influence the rate of sea-level rise. In addition to ocean mass and volume effects, changes in ocean currents may influence regional climate trends and through undulations in ocean water topography impose an additional effect on the apparent rise of sea-level. Such effects may be rapid, which may explain the observed fast transitions in the rates of relative sea-level rise at Clinton and the northeastern U.S. seaboard.

THE CORRELATION PROBLEMS OF MARINE AND CONTINENTAL OXYGEN ISOTOPE DIAGRAMS OF THE ARCTIC FOR THE LAST 40,000 YEARS

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Oxygen isotope diagrams received from different objects such as plankton and benthos foraminifera of bottom drill core, ice core of polar ice sheets, and sequences of ground ice have different degrees of detail and interruption in time. They are considerably different in authenticity of age determination. One of the most effective paths in deciding the contradiction and to overcoming the restriction of oxygen isotope indication of every oxygen-containing system is their chronological correlation and joint paleoclimatic and paleoglaciologic reconstructions. We have studied oxygen isotope diagrams of ground ice for the last 40,000 years and proposed the quantitative criterion for separation of diagrams by oxygen isotope zones (Vasil'chuk, 1987). As a standard of oxygen isotope zone is selected the $\delta^{18}O$ average meanings of recent ice wedges or winter precipitation (they are identical). As for different regions of the Northern Hemisphere the meanings of $\delta^{18}O$ in recent ice wedges has fluctuated in Western Siberia from -16 to -20‰, in Northern Yakutia from -24 to -28‰, and in North-West Canada from -22 to -26‰. Oscillations of $\delta^{18}O$ in ice wedges which were forming the last 40 kyr consist of ±6-8‰ from this range. It is necessary to make similar investigations for the ice cores of Arctic islands. The separation by oxygen isotope zones may be correct with standard 2-4‰, as means of the last 40,000 years differ from the modern ones as a rule by ±10-12‰.

The situation with foraminifera oxygen isotope diagrams of the Northern Atlantic Pacific and Arctic is more complicated. The changes of $\delta^{18}O$ consists of ±4‰ as compared with modern ones. It may suggest the separation of oxygen isotope zones with standard 1‰ if the means have fluctuated by ±3-5‰, and with standard 0.5‰ if the mean is about 1-2‰.

The study shows the correlation of marine and continental oxygen isotope diagrams of different regions of the Northern Hemisphere.

SUBMARINE MORPHOLOGY OF THE UPPER INDUS FAN: AN APPRAISAL

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A reconnaissance survey was carried out along the northwestern continental margin of India off the Gulf of Kutch and the adjoining upper Indus Fan, for studying the morphology and structure. High-resolution echo-sounding (3400, 1 km) and shallow seismic (2200, 1 km) data were obtained along nine NE-SW trending tracks spaced at 20 km intervals. These studies reveal for the first time the presence of a fascinating deep, active large-scale submarine canyon stretching from 22°20'N to 21°20'N which is perched by spectacular levees. The canyon commences from the continental slope at a water depth of 1230 m in the surveyed area and extends up to 2200 m. It is about 8 km wide in the northern proximal end, about 13 km in the center, which constricts to about 6 km towards the distal downstream. The canyon is 350 m deep in the north, whereas it shallows down to 195 m towards the south with steep-faulted flanks. The surrounding levee system is also characterized by extensive faulting. Besides this active canyon, the proximal part of the upper fan is marked by several small-scale canyons lineating towards the south. The configuration of the canyon and the channel levee complexes are discussed with reference to sea-level fluctuations, tectonics, mass movement and turbidity currents.

Further, it is surmised that diapiric structures, as evidenced in the records, might have played a significant role in controlling the fault configuration in the area.

RECOGNITION OF CYCLIC AND NON-CYCLIC ENVIRONMENTAL CHANGES IN THE MEDITERRANEAN PLIOCENE: A PALYNOLOGICAL APPROACH

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The interval between 2.8 Ma and 2.3 Ma BP from the south Italian Singa section has been investigated for its dinoflagellate cyst and sporomorph contents. Calibration of changes in the amounts of sporomorphs relative to dinoflagellates (S/D ratio) against the computed isolation curve, lead to an improved age assessment for the section. Changes in the S/D ratio are best explained by changes in runoff. The 23 ka and 41 ka frequency components of the S/D ratio, the ratio between 'warm' and 'cold' water dinoflagellate cysts and the already available $\delta^{18}O$ curve are classified in (1) a group with short response time to orbital forcing and (2) a group with longer response time. Those signals having a short response time are attributed to local precipitation-induced changes in runoff. Those signals having a longer response time are mainly attributed to changes in global temperature and to a lesser extent to changes in global ice volume. Furthermore, increased relative amounts of *Protoperidinioid* dinocysts associated with high S/D values indicate that increased productivity is associated with increased runoff.

THE ENRICHMENT OF ^{13}C IN MARINE KEROGEN DURING LATE OLIGOCENE AS THE RESULT OF A COINCIDENCE OF THE DROP IN ATMOSPHERIC CO_2 LEVEL AND THE ENRICHMENT OF ^{13}C IN DISSOLVED OCEANIC CARBON

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Two of the authors (I. Vető and E. Hertelendi) recently stated that the decrease of marine photosynthetic carbon isotopic fractionation leading to a separation of the ^{13}C-depleted old and the ^{12}C-rich young marine kerogens took place prior to the Early Oligocene. Here, the authors try to delineate the time interval of this decrease.

The studied Oligocene-Early Miocene sediments from Hungary, Carpthians, and ODP Hole 682A (Peru offshore) represent very different paleoenvironments from the point of view of distance of coast, productivity, salinity and bottom-water content. Techniques used were kerogen $\delta^{13}C$ determination, Rock-Eval pyrolysis and GC of the free saturated hydrocarbons.

The increase of hydrogen index is considered to reflect an increase of percentage of marine components in kerogen. This assumption is supported by the saturated HC spectrum as revealed by GC.

Average $\delta^{13}C$ of the marine kerogen in the NP 24 biozone samples (Carpathians) is less negative with about 2 ‰ than that in the NP 21-23 biozone samples (Carpathians and Hungary). Based on Peru offshore samples another 2 ‰ shift in the same direction took place during the Early Miocene where no significant shift occurred. The approximately 4 ‰ shift of $\delta^{13}C$ during the Late Oligocene can be explained by a drop in atmospheric CO_2 level and to a lesser extent by an enrichment of ^{13}C isotope in oceanic dissolved carbon.

OLIGOCENE CALCAREOUS NANNOFOSSIL PALEOCLIMATIC IMPLICATIONS IN THE EQUATORIAL INDIAN OCEAN SITE 709 (LEG 115): COMPARISON AND CORRELATION WITH PLANKTONIC FORAMINIFERA

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Leg 115, Site 709 in the Equatorial Indian Ocean (lat. 03° 54. 90' S) provided a relatively extended Oligocene sedimentary sequence. The biostratigraphic studies previously performed on calcareous nannofossil and planktonic foraminifera spanning the interval from Zone CP17 through CP19b, and Zone P20 through P22 respectively, revealed that both calcareous nannofossil and planktonic foraminifera fluctuate in abundance, distribution and species diversity throughout the sequence.

Assuming that these fluctuations could be related to paleoclimatic variations, quantitative analyses were performed on floral and faunal assemblages in order to verify their possibly correspondent response to paleoclimatic changes. Percent abundance curves were constructed for some selected species and groups and for the paleoclimatic indices using **1a)** *Cyclococcolithus formosus, Sphenolithus* and *Discoaster* groups as calcareous nannofossil warmer indicators, and **1b)** *Cassigerinella, Dentoglobigerina altispira, "Globigerina" ciperoensis*, and turborotaliids as planktonic foraminifera warmer indicators, and **2)** *Globorotaloides, Catapsydrax, Globigerina* s.s. *S. angiporoides* and *Tenuitella* groups as planktonic foraminifera cooler indicators. The climatic curves were also constructed using planktonic foraminifera warm and cool indicators. The abundance trends of calcareous nannofossil and planktonic foraminifera warm indicators are almost consistent and sometimes roughly parallel through the sequence. Moreover, abundance curve of calcareous nannofossil warm indicators fluctuate mostly in phase with the climatic curve based on planktonic foraminifera.

The paleoclimatic interpretation of calcareous nannofossil data suggest that warmer episodes occur the middle-upper Eocene, as well as a cooling event at the Eocene/Oligocene boundary. Moreover, both microfossil groups data suggest that cooler conditions characterize the lower Oligocene. Warmer conditions prevailed in the upper Oligocene but were not definitely settled in its uppermost part as indicated by the decrease in abundance of warmer indicators.

MOLECULAR INDICATORS OF PALAEOPRODUCTIVITY: TOTAL PIGMENT AND ALKENONE-ALKENOATE ABUNDANCES AS PRIMARY BIOMASS INDICATORS COMPARED TO TOC AND COCCOLITH ABUNDANCES

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Organic compounds found in marine sediments can provide information about their source of input to the environment (e.g., marine or terestrial; algae, bacteria, zooplankton) and about the water conditions at time of deposition (e.g., hypersalinity, oxicity/anoxicity) as well as about the prevailing climatic conditions (e.g., sea-surface temperature, pCO_2, upwelling, wind stress).

We show how particular organic compounds measured down a piston core can be used to indicate fluctuations in total primary productivity (via total abundance of pigments) and the productivity of *Prymnesiophyte* algae (via alkenone-alkenoate abundances:AA). The core is PC12 from the continental slope off Walvis Bay in Southwestern Africa, a zone of intense upwelling in the Benguela Current. Our palaeoproductivity data are compared with total organic carbon, coccolith abundances, sea-surface temperatures derived from the U^{k}_{37} index and $\delta^{18}O$ stratigraphy.

Diagenetic effects, as well as degradation of the pigments and the AA in the water column, have to be taken into account when relating the values found in the sediment with those from surface waters in order to derive absolute primary productivity. The pigment results correspond to marine inputs, whereas the TOC data from areas close to coastal environments may have a strong terrestrial influence.

TRIASSIC RIFTING AND TETHYAN PALEOENVIRONMENT OF A NE-GONDWANAN PASSIVE MARGIN (NEPAL)

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The Mesozoic sediments of the Thakkhola (central Nepal) were deposited on a broad Eastern Gondwanan passive margin at mid-latitudes (28-41°S) facing the Southern Tethys ocean to the north. The facies is strikingly similar over a distance of several thousand km from Ladakh in the west to the paleogeographically adjacent NW Australian margin (Exmouth Plateau, ODP Legs 122/123) and Timor in the east. Late Paleozoic rifting led to the opening of the Neo-Tethys Ocean in Early Triassic times. An almost uninterrupted, ca. 2

km-thick sequence of syn-rift sediments was deposited on a slowly subsiding shelf and slope from Scythian (Early Triassic) to late Valanginian times when breakup between Gondwana (NW Australia) and Greater India formed the proto-Indian Ocean. We report from two international "Lost Ocean Expeditions" (1988 and 1991), led by F. Gradstein, and studies of the stratigraphy and paleoenvironment of this sequence.

The sedimentation is controlled by (1) global events (eustasy; climatic/oceanographic changes due to latitudinal drift; plate reorganization leading to rift-type blockfaulting), and (2) local factors, such as varying fluviodeltaic sediment input, especially during Permian and late Norian times. Sea level was extremely shallow in Permian, high in Carnian and low again during Rhaeto-Liassic times. Third-order sea-level cycles were distinguished in the late Scythian, Carnian and late Norian to Rhaeto-Liassic (where they can be correlated with the Exmouth Plateau sea-level record).

During the Permian(?) pure quartzitic sand and gravel were deposited as a shallowing-upward series of submarine channel or barrier island sands. The high compositional maturity is typical of a deeply weathered, stable craton-type hinterland, uplifted during a major rifting episode.

During the Scythian a 20-30 m thick, composite, condensed sequence of nodular "ammonitico rosso"-type marlstone with a "pelagic" ammonite-pelecypod- calcisphere-ostracode-fauna was deposited (Tamba Kurkur Formation). This indicates rapid tectonic subsidence and sediment starvation during the transgression of the Neo-Tethys ocean.

After a hiatus, a 400 m thick sequence of fining-upward, filament-rich wackestone/shale cycles was deposited in a bathyal environment (Mukut Limestone/Thinigaon Formation, Carnian). This is overlain by about 300 m of sandy shale and siltstone intercalated with quartz-rich bioclastic grain- to rudstone (Tarap Shale, late Carnian-Norian).

The upper Norian to (?lower) "Rhaetian" Quartzite Series ("Thini Formation", 250 m) consists of (sub)arkosic sandstones, rich in K-feldspar (and/or mica) and purely quartzitic sandstones, indicating different sediment sources. The fluviodeltaic sandstones are intercalated with silty shale, coal, bioclastic limestone (including algal bindstone and mollusc floatstone), as well as mixed siliciclastic-bioclastic rocks. The depositional environment was marginal-marine to shallow-subtidal. The fluviodeltaic influence decreased towards the overlying carbonates of Rhaeto-Liassic(?) age (Kioto Limestone = Jomosom Formation), when the region entered tropical paleolatitudes resulting in platform carbonates and local reefs (Exmouth Plateau).

ORGANIC MATTER IN PELAGIC SEDIMENTS OF THE NORWEGIAN-GREENLAND SEA: GLACIAL/INTERGLACIAL VARIATIONS AND IMPLICATIONS OF THE PRESERVATION OF MARINE ORGANIC MATTER

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Detailed organic geochemical and organic petrological analyses focussing on the glacial/interglacial contrasts were performed on three sediment cores from an east-west transect (67°-70° N) in the Norwegian-Greenland Sea (NGS). The results reveal distinct temporal and spatial variations in quantity and composition of organic matter, reflecting changes of the depositional environment and provenence of the organic fraction.

In the two western cores total organic carbon content (TOC) and accumulation rates for the last two glacial/interglacial transitions show distinct pulses of TOC up to 1 wt.% during glacial and deglacial phases, documenting an increased sedimentation of fossil organic carbon and IRD due to glaciomarine sedimentary processes. A pronounced lateral gradient shows that the glaciomarine sediment input degrades strongly towards the central part of the NGS. A Rock-Eval data, C/N ratios, $\Delta^{13}C_{org}$ and microscopic results, provided from bulk sediment analysis, clearly indicate the dominant terrigenous or reworked character of the organic matter. This result is supported by the occurrence of coal and black shale fragments >500 µm. Coarse grained huminites/vitrinites are angular to sub-angular, suggesting a nearby source of organic-rich sediments most favorable along the Norwegian and Barents Sea shelves.

Interglacial deposits in general are determined by very low TOC contents that are, in most cases, less than <0.2 wt.%, a minimum baseline typical for the world's pelagic ocean. The organic fraction is made up by highly oxidized organic matter, i.e., inertinites. Isotope stage 5.5.1 (Eem-interglacial), a fossil equivalent to the recent climatic and oceanographic conditions with high marine productivity, is only preserved in the record of the high accumulating core 23071.

Towards the sediment surface, there is a clear increase of TOC up to 1 wt.% along with a relative increase of the marine organic fraction. The pronounced downcore decrease of TOC in the upper sediment section reflects the almost quantitative decay of the autochthonous signal due to oxic respiration and benthic activities.

SOME GEOLOGICAL CONSEQUENCES OF THE LATE DEVONIAN - EARLY CARBONIFEROUS MANTLE SUPER-PLUME OF THE SUDETES MOUNTAINS, SW POLAND

B. Wajsprych (Institute of Geological Sciences, PAN, Wroclaw, Poland)

The Late Devonian-Early Carboniferous Sudetic mantle superplume (SMSp) seems to be the source of some tectonic, sedimentary, paleoceanographic and other processes and events.

First of all, it is responsible for big masses of basic and ultrabasic material incorporated at the Late Devonian time into shallow parts of the crust - this process is quite comparable to the mid-Cretaceous stage on enormous production of the oceanic crust, known as the Mid-Cretaceous mantle superplume (MCSp) stage (Larson, 1991 ab). Therefore, the Mid-Sudetic basites and ultrabasites are considered to be mostly products of oceanic spreading (Borkowska, 1985; Dziedzic, 1985; Pin et al., 1988).

A closed coincidence of the SMSp with a longer stage of constant, reversed, magnetic polarity (Irwing and Pullaiach, 1976; modified Harland et al., 1989) is well-expressed, but only for the first stage of the SMSp development, to the time span of basic-ultra-basic plutonism.

Also other processes and events, e.g., increase of CO_2 production due to mantle degasation, increase of siliceous sedimentation in ocean-type basins, warming of climate, eustatic movements, black shale sedimentation, increased oil generation, are considered to be eological attributes of super plumes and are noted in the Sudetes Mts. region.

If Mid-Sudetes plume is really superplume, as it is postulated here, this event has to be noted worldwide. Many arguments seem to support such an idea. Works of Weissbrod and Gwirtzman (1988/89) and Husseini (1991) concerning the Late Paleozoic updoming in the Near East allow one to think more safely about the Late Devonian deep-mantle intervention in the history of the Earth crust.

References: Borkowska M., 1985, Geol. Sudetica 20:3-35; Dziedzic H. 1985, Krystallinikum:7-27; Husseini M.I.,1991, AAPGBull: 108-121; Larson R., Geology19, 963-966; Pin O. et al., 1988, Lithos 21:195-209; van Breemen O. et al., 1988, An.Soc.Geol.Polon, 58: 3-19.

THE LATE DEVONIAN - EARLY CARBONIFEROUS MANTLE SUPERPLUME CONCEPT: ITS LITHOTECTONIC AND TECTONO-STRATIGRAPHIC EVIDENCE IN THE SUDETES MOUNTAINS

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Such a mantle plume is able to be defined in the Mid-Sudetes where there are well-known tectono-stratigraphic relations of the U. Devonian/357± 12 Ma from Nd-Sm isotope studies (Pin, 1988), undeformed and unmetamorphosed mafic and ultramafic rocks to crystalline basement noted there by the Sowie Góry gneiss (Sgg) and to the U. Famennian -L/M Visean marine sedimentary cover. The SG gneisses have undergone high-grade metamorphism ca 380 Ma ago, then, ca 370 Ma ago, they were rapidly uplifted up to the surface, if one notes the L. Famennian age of sediments covering both the SG gneiss and gabbros.

The coincidence of this dramatic uplift of deep continental crust portion and deep-rooted basic to ultrabasic plutonism suggests the mantle plume as one common and powerful reason.

The following data: - 380 Ma as age of high-grade metamorphism in the SG gneiss, - 370 Ma as cooling age for this gneiss, and L. Famennian (ca 365 Ma after Harland's et al. (1989) time scale) age of marine transgression - allows establishment of the Devonian time as a period of the mantle plume high activity.

The L. Famennian marine transgression starts deposition of carbonate-black shale shale-silicoclastic Wapnica-Nowa Wies sequence (W-NWs) of passive platform recording a stage of crustal extension, then closed in the E/M Visean time, when the foreland-type sedimentation and stage of compressional regime had been started.

A presence of a well-documented stage of crustal-scale extension at W-NW-time is seen here as recovering a prolongation of the mantle plume activity up to 342-345 Ma ago (Using this Harland's time scale again).

In Conclusion, a time span between ca 375 Ma and ca 345 Ma ago, i.e., late L. Devonian-E/M. Visean time has been a period of strong activity of the L. Devonian-E. Carboniferous mantle superplume.

PORE WATER PROFILES, DIAGENESIS AND UPWELLING: AN EXAMPLE FROM THE BENTHIC BOFS TRANSECT TOWARDS NW AFRICA

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As part of the UK BOFS contribution to JGOFS, a suite of sediment samples was obtained on a transect fom the deep Atlantic in towards the NW African margin during Cruise 53 of *RRS Charles Darwin.* Both box and kasten corers were employed and the pore waters extracted on board have been analyzed subsequently for nitrogen species, silica, phosphate and manganese. The geochemical profiles show significant increases in the rate of nitrate depletion within the sediments as the water depth decreases, and a concomitant decrease in the depth within the sediment column at which manganese remobilization takes place. In contrast the silica profiles are virtually identical. These results are interpreted as showing variable and increasing organic carbon input to the sediments as the continental shelf, and hence the upwelling zone, is approached. In the case of silica, however, either the input signal is constant or the rate of silica dissolution within the upper half meter or so of the sediment pile is such that any variability in input of this component is masked by *in situ* processes within the sediments.

THE LAST DEGLACIATION IN THE SOUTH CHINA SEA

P. Wang (Dept. of Marine Geology, Tongji Univ., Shanghai, China), I. Wang, and Y. Bian

A total of 36 sediment cores covering the last glaciation - Holocene transition has been studied to various degrees and used to interpret the paleoceanography of the South China Sea. Although in most cases the sampling interval was over thousand years, recent studies of Core V36-3 from the northern slope (19°00.5'N,116°05.6'E, water depth 2809 m) provided a high resolution stratigraphy with 36 samples since last glacial maximum. During the last deglaciation, the oxygen-isotope value in Core V36-6 had lightened by 1.23‰, whereas summer and winter SST had increased by 3.4°C and 1.9°C, respectively.

Two major events within the last deglaciation have been recognized from the studied cores, particularly Core V36-3:

1. A rapid increase in $CaCO_3$% and decrease in carbonate dissolution (Foraminiferal Dissolution Index) at about 12 ka BP. This "preservation maximum" coincides with a peak in the organic carbon curve and may indicate an enhanced productivity. At sites below the present lysocline sedimentation rate and $CaCO_3$ content decreased rapidly after the event, but only the non-carbonate component noticeably declined above the lysocline. These results suggest a reduced supply of terrigenous clastics and decreased carbonate ion concentration at ca. 12ka BP in the South China Sea.

2. An abrupt cooling event at approximately 11.0 ka BP, presumably comparable with Younger Dryas, is revealed in Core V36-3. The event started as a SST decrease of 2.7°C for winter and 0.9°C for summer, followed by a rapid temperature rise to a postglacial level at about 8.5 ka BP. The cooling was caused by a reduction of the tropical Pacific warm water (Kuroshio) and accompanied by decreased $CaCO_3$ in the sediment. The changes probably are related to the closer proximity of river estuaries and the enhanced fresh-water influence.

PLIO- AND PLEISTOCENE SEA -SURFACE TEMPERATURE HISTORY OF THE WESTERN PACIFIC

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The Plio- and Pleistocene was a time of cryosphere development in the northern hemisphere. The present study is based on quantitative planktonic foraminiferal data of 344 samples from 8 DSDP sites in the western Pacific. Target transform has been applied to the classic transfer function approach to overcome the major no-analog condition caused by evolutionary faunal changes. Experiments on application of this technique have been successively carried out in combination with time-slice and time-series studies, which backtrace the history of sea-surface temperature (SST) field in the last 5.3 Ma. Although the data base in the present study is close to the statistical limits of factor analysis, the clear presence of sensible variations in individual SST time series suggests the feasibility and reliability of this method in paleoceanographic studies. The result shows that during the last 5.3 Ma there existed three major cooling events in early Pliocene (C-I: 4.9-3.5 Ma), late Pliocene (C-II: 3.1-2.7 Ma), and latest pliocene to early Pleistocene (C-III: 2.2-1.2 Ma). Cooling events are reflected in the increase of seasonality (3-5°C) and steepening of SST gradient in the subtropical area. In the western Pacific, the subtropics were much more sensitive to climatic force of cooling than the tropics, and cooling events in the cooler subtropics usually preceded those in warmer subtropics by 0.1-0.2 Ma in the Pliocene. The latest Pliocene to early Pleistocene cooling is different from the previous two in its irreversible, steplike decrease in SST, which established the glacial climate characteristic of the late Pleistocene. Moreover, this cooling event displays a gradual SST decrease at warmer subtropical sites (6-7°C for winter, 1-2°C for summer), while that at cooler subtropical sites shows an abrupt SST reduction (5-6°C for winter, 2°C for summer). In contrast, the equatorial and tropical western Pacific experienced only minor SST change in the last 5.3 Ma. It is evident that in the low-latitude western Pacific, the cooler subtropics are most sensitive to climatic forcing from the north. The three cooling events in the last 5.3 Ma can be correlated to, or may be the result of, Antarctic ice-volume fluctuation (C-I), closing of the Central American seaway and hence the change of general circulation pattern (C-II), and finally, the cryosphere development with an intensive increasement of the northern hemisphere ice sheets (C-III).

THE TERRESTRIAL AND MARINE RECORD OF CENOZOIC GLACIATION IN THE SOUTHERN HEMISPHERE

P.-N. Webb (Dept. of Geological Sciences, Ohio State Univ., Columbus, USA) and D.M. Harwood

Cenozoic climate in the Southern Hemisphere (S.H.) was controlled by latitudinal movements and elevational adjustments of lithospheric plates, and by evolution of complex marine gateways and passages between the numerous S.H. lithospheric elements. The development of deep water circum-Antarctic circulation, circum-Antarctic orogenesis, mountain ranges close to coastlines, retention of Antarctica in a polar position and widespread volcanism, were among the significant events in the Cenozoic of the S.H.. These complex and widespread events did not result in a single and synchronous pan-hemispheric paleoclimate record in the terrestrial and/or marine realms. The climatic impact of these phenomena varied through the Cenozoic according to their geographical extent, relationships between events and degree of synchroneity among events. The documentation of discrete, high-frequency cryospheric perturbations in several S.H. landmasses, by use of marine proxy record, should be difficult at best and perhaps impossible. Glacial and deglacial events are recognized in upper Eocene - Oligocene terrestrial and/or inshore marine records at three widely separated locations in Antarctica and indicate some of the earliest ice mass development on the continent. Paleogene glaciations have not been documented at other terrestrial or shallow marine localities in the S.H., but some of these events have possibly been detected in Atlantic and Pacific deep-sea proxy records, and in the sequence of stratigraphy records of low-middle latitude continental shelves. Multiple glaciations are recognized in low-middle Miocene in shore marine records of Antarctica but linkage with the deep sea proxy and lower latitude continental shelf records is not yet established. Upper Miocene - Pliocene terrestrial glacial-deglacial events are known in Antarctica, Argentina and Bolivia; and in near-shore and deep-sea data documented at localities in Antarctica. Northward shifts in vascular plant biogeographic boundaries in parts of Antarctica, the subantarctic islands, New Zealand, Australia and New Guinea, during the late Mio-, Plio- and Pleistocene, probably represent the combined effects of glacial events in Antarctica and alpine glaciation associated with late Cenozoic mountain building around the Pacific rim. Relationships between the Pliocene - Pleistocene glacial histories of the southern and northern hemispheres are both poorly understood or correlated.

PLANKTIC FORAMINIFERAL ASSEMBLAGE DISTRIBUTION OF THE TROPICAL PACIFIC AS BASIS FOR PALEOTEMPERATURE RECONSTRUCTION: AN EVALUATION USING PATTERN RECOGNITION TECHNIQUE

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The distribution patterns of planktonic foraminiferal assemblages in deep-sea sediments have been used as modern analogs by authors to reconstruct past sea-surface temperatures (SST). A fundamental premise for such an approach, however, whether the composition data indeed reflect the sea-surface temperature sufficiently, has not been thoroughly investigated. The planktonic foraminiferal composition of 516 core-tops in the tropical-subtropical Pacific was evaluated, using a pattern recognition technique, Soft Independent Modeling of Class Analogy -- Modeling and Classification Using Partial least squares (SIMCA-MACUP). The analysis proceeded with two phases: training and testing. During the training phase, 3/5 of the coretops were used to "train" the computer to predict the SSTs while in the second phase, the SSTs of the remaining coretops were predicted and then compared to the observed values. The separation of training from testing allows an objective test of the accuracy of the prediction.

An initial principal component analysis showed that the variance in the faunal composition is mainly controlled by differential dissolution. The data were next divided into three subsets according to their dissolution intensity based upon the relative abundance of dissolution-resistant species in samples. Results from the training phase showed that the variation in each subset is poorly correlated to the SSTs of August and February. Results from the testing phase showed that the prediction errors are normally distributed, ranging from -6 to +5°C. The geographic pattern of the prediction errors is similar to that of the temperature difference between the reconstructed SST of the last glacial maximum at 18 ka (CLIMAP) and the present SST. This suggests that the reconstructed SST at 18 ka reflects to some degree artifacts imposed by the data structure.

BATHYMETRY AND COARSE FRACTION COMPOSITION OF VIKING-TROUGH CENOZOIC SEDIMENTS

M.H. Weinelt (GEOMAR, Kiel, Germany), E.Steurbaut, and D. Spiegler

Establishing paleobathymetric estimates for the Cenozoic North Sea is still a major problem. Benthic foraminifer assemblages indicate water depth of more than 3 km for the Paleogene, a figure far from being reasonable for an epicontinental sea. As an alternative source for information on sea-level changes, sequence stratigraphy and the Haq-curve were utilized to give estimates on the bathymetric development in the Cenozoic northern Viking Trough. A water depth of at least 900 m can be attributed to the early Paleogene basin center, whereas a middle Miocene to early Pliocene hiatus indicates 0-value water depth.

The estimated paleo-water depth allows one to isolate the dependency of the sediment composition on water depth from the observed sedimentation history. Planktic foraminifers, for instance, turned out to be most common in northern Viking Trough sediments of an assigned depositional water depth close to 400 m. Non-calcareous benthos, on the other hand, shows maximum amounts for values of 500 to 600 m (agglutinated foraminifers) and 100 to 250 m (siliceous sponge spicules). Similar evaluations are performed for different biogenic, clastic and authigenic sediment components and component groups.

MELTWATER EPISODES IN THE NORWEGIAN-GREENLAND SEA DURING THE LAST 60,000 YEARS

M.S. Weinelt (Geologisch-Paläontologisches Institut, Kiel, Germany), M. Sarnthein, M. Arnold, H. Erlenkeuser, and E. Jansen

High-resolution stable isotope records of *Neogloboquadrina pachyderma* sin. from the Norwegian-Greenland Sea and the northern North Atlantic show five to seven short meltwater episodes in isotope stage 3 (at 60,000 - 26,000 years BP), one distinct episode centered at the Last Glacial Maximum (18,000 radiocarbon yrs ago), and two major deglacial meltwater pulses culminating near 13.6 and 12.3 ky, slightly subsequent to the Heinrich events. Age control is based mainly on AMS-^{14}C ages from 8 cores, revealing sedimentation rates of 6 - 100 cm/1000yrs, the dating of δ^{18}O event 3.33 is based on the SPECMAP time scale.

Based on δ^{18}O records from up to 60 sediment cores, the iceberg and meltwater dispersion during stage 3 was traced from source regions near of the Lofotes and possibly on the eastern Greenland Shelf into small scale anti-clockwise circulation gyres, including a narrow branch of warm water advection penetrating to 65°N. In contrast , the peak glacial and early deglacial meltwater plumes spread from the western Barents Shelf (71 - 73°N) and suggest clockwise circulation gyres reaching south to the west of Ireland. The deglacial and peak glacial meltwater episodes were linked to low planktic δ^{13}C values which almost covered the complete Norwegian-Greenland Sea and show strong minima along the northeastern margin and in the North Atlantic west of Ireland. The preglacial episodes, however, showed a more patchy δ^{13}C distribution pattern with modest maxima northeast of Iceland (up to 0.35% PDB), which suggest local deep water formation in the Norwegian Greenland Sea, the overflow of which is also recorded in the benthic δ^{13}C record west of Rockall Bank during this time.

REPEATED EXTRINSIC PERTURBATIONS OF THE CRETACEOUS BIOSPHERE - A DOCUMENT FROM NORTHERN TETHYAN SEDIMENTS

H. Weissert (Geological Institute, ETH-Z, 8092 Zürich, Switzerland), K.B. Föllmi, and A. Lini

Cretaceous shelf sediments deposited along the former northern margin of the western Tethys are preserved in the Helvetic tectonic nappe complex of the Swiss and western Austrian Alps. Hemipelagic carbonates accumulated along the outer shelf provide a $\delta^{13}C$ record of major perturbations of the global carbon cycle and hence of the biosphere.

The carbon-isotope stratigraphy established in these hemipelagic carbonates allows the identification of two major positive carbon-isotope excursions. These carbon-isotope events correlate with those globally recognized during the late Valanginian and Aptian time intervals, and which are interpreted as documents of accelerated global carbon cycling during times of episodic greenhouse climate conditions.

The positive carbon-isotope events can be linked to the drowning of the carbonate platforms forming the inner shelf of the northern Tethys. The drowning phases identified in the Valanginian and Aptian produced pronounced unconformities that developed during periods of sea-level rise following high stand carbonate deposition and consequent reduction in carbonate production. Their formation was accompanied by significant phosphogenesis, glaucogenesis, and the influx of coarse-grained siliciclastics.

The temporal coincidence of accelerated carbon cycling, increased availability of phosphorus, increased detrital influx, pronounced sea-level rise, and platform drowning is thought to reflect the dynamic response of the biosphere to extrinsic perturbations. These perturbations were most likely triggered by episodic flood-basalt volcanism causing an enlarged input of primordial CO_2 into the atmosphere.

SEASONAL TRENDS AND PRESERVATIONAL BIASES OF POLYCYSTINE RADIOLARIA IN THE NORTHERN CALIFORNIA CURRENT SYSTEM

L.A. Welling (College of Oceanography, Oregon State Univ., Corvallis, USA) and N.G. Pisias

We have analyzed a two-year sediment trap record of seventy-six species of Radiolaria from three locations across the northern California Current System. Q-mode factor analysis identifies the fundamental trends in the radiolarian data with a six-factor model that explains 89% of the trap data. All six factors tend to have both temporal and spatial features which reflect the various physical environments of the eastern North Pacific. The most prominent trend is this data set appears to be related to the seasonality of the Californian Current. Two factors illustrate this: the California Current factor, which exhibits its strongest influence during summer and fall and the winter factor, which is most important in the winter and spring. Both of these factors are most important in the coastal region extending to around 300km offshore. Together they account for > 50% of the information in the trap samples from the two moorings located in the coastal environment. The oceanic environment sampled by the mooring 650km offshore is strongly influenced by transitional waters and those from the Central and Subarctic regions.

Spatial distribution of the trap factors in the surface sediments beneath the California Current System generally support the oceanographic interpretations we have made based on the temporal and spatial patterns they exhibit in the traps. However, each of the individual factors explain less information in the surface sediments than they do in the traps above them where they are defined. Overall the trap factor assemblages account for about 50-60% of the radiolarian data in sediments beneath the mooring sites. A factor model using only robust species reveals the same basic trends as the model which considers all species but is able to describe a larger fraction of the sediment data (63-91%). The high communality of the "reduced species" model is primarily due to very high estimates of one factor in the coastal sediments, the California Current factor. This factor explains 69% of the information in the sediment beneath the Nearshore mooring site vs. only 32% of the trap data at that site. This discrepancy suggests that either 1) these two years of trap data are anomalous and have underestimated the predominance of the California Current assemblage, 2) species associated with this factor are consistently more productive than other species or, 3) application of the "reduced species" model to the sediment presents a distorted view of the relative importance of various oceanographic environments, even though this model has high sediment communalities. While we cannot categorically eliminate any possibilities, we suggest that development of a more sophisticated model is warranted.

LATE QUATERNARY HISTORY OF THE LEEUWIN CURRENT: A UNIQUE, SOUTHWARD-FLOWING, EASTERN-BOUNDARY CURRENT IN THE INDIAN OCEAN

P. Wells (Geology Dept., National Univ., Australia) and P. De Deckker

The Leeuwin Current (L.C.), a seasonal, southward flow of warm, low-salinity tropical water off Western Australia, is the only southward-flowing current to occur on the eastern margin of a major ocean. It has close associations with global-scale climate changes - in particular the El Nino/Southern Oscillation (ENSO). At present, the L.C. is strongest during winter, and during anti-ENSO years when the flow of warm tropical Pacific water through the Indonesian Archipelago is greatest. At these times, coastal sea-level off Western Australia rises, with significant influences on coastal fishing industries.

We are studying the history of the L.C. over the last 125,000 yrs through the application of CLIMAP-style transfer functions to population statistics of planktonic foraminifera accumulated in ten deep-sea cores in the vicinity of the Current. Our results indicate that at the Last Glacial Maximum (LGM), the L.C. did not flow and there was a major reorganization of the oceanographic regime offshore Western Australia.

At this time also, upwelling off Peru is known to have ceased, which we infer was due to major changes in the oceanography of the Pacific Ocean, associated with the same mechanisms that drive the Leeuwin Current.

With the cessation of the Leeuwin Current at the LGM, the cold, northward-flowing West Australian Current, that today operates beneath the L.C. to depths of about 2000m, became the dominant ocean current affecting the Western Australian coast. This major event culminated in upwelling of cold waters off North West Cape (110°E, 22°S), producing sea-surface temperatures significantly cooler than expected along today's N-S temperature gradient.

Data for 125,000 yrs. BP indicate that the L.C.operated and that sea-surface temperatures were similar to today, except off North West Cape where temperatures were 2°C cooler, and off Perth (115°E, 32°S), where summer sea-surface temperatures were up to 3°C warmer.

SEDIMENTS OF THE ICELAND FAROE RIDGE: OVERFLOW CIRCULATION CONTROLING BEDFORM PATTERNS

F. Werner (Geologisch-Paläontologisches Institut, Kiel, Germany), W. Dorn, and D. Milkert

The overflow circulation entering the North Atlantic via Iceland Faroe ridge and the Faroe Channels give rise to a multitude of sorting effects and bedform formation which raises the following background questions: 1) how "good" is the coincidence between the oceanographically and sedimentologically determined qualities of flow direction and power? 2) Should it be possible to infer bed load transport rates from comparison of temporally differing, sonographically surveyed bedform patterns? 3) Does a main sediment stream exist on the southern slope and, if so, which is its exact geographic position?

A slope-parallel channel system on the southern slope of the ridge with overflow current-controlled, asymmetrical sediment fillings permits study of the development of the overflow currents by means of sediment cores taken from opposite channel flanks. Due to Coriolis forces, the northern flanks show condensed sedimentation and slightly increased grain sizes contrasting with the relationships on the opposite flanks.

The age-dating of the cores shows that the modern overflow system was re-established since Termination Ia. Associate problems dealt with are the question of maximum water depth of iceberg plough marks, a possibly biologic origin of huge blocks apparently related to water mass boundaries, and the composition of contourites as manifested in the bedforms.

BENTHIC FORAMINIFERAL MORPHOTYPES AND PRIMARY PRODUCTION DURING THE TERMINAL CRETACEOUS

J.G.W. Widmark (Dept. of Paleontology, Univ. of Uppsala, Sweden)

In the present marine environment, some benthic triserial and biserial foraminiferal ("buliminid") morphotypes have been found to represent high nutrient supply and/or low oxygen levels. If these morphotypes have the same environmental requirements as their fossil counterparts, the fossil record could give some information on the the nutrient supply (primary production) to the sea floor of the ancient ocean.

Six DSDP sites have been analyzed for terminal Cretaceous deep-sea benthic foraminifera in order to quantify the proportions of the various morphotypes, and to investigate whether differences in the proportions of various morphotypes are related to time, different paleolatitudes, and/or different paleodepths. The material studied was obtained from the low-latitude Site 465 (Pacific Ocean), and the intermediate-latitude Sites 384 (North Atlantic) and 356, 516, 525, and 527 (South Atlantic). The material analyzed represents a time-slice of about 50 k.y. of the terminal Cretaceous.

In the material studied, an important trend is observed in the relative abundance variations in heavily calcified "buliminid" morphotypes (i.e.

buliminids and Aragonia spp.), and various trochospiral taxa. The first morphogroup dominates the faunas at the sites from the Tethyan Realm that lie outside the South Atlantic (Sites 465 and 384), whereas the South Atlantic Sites 356, 516, 525, and 527 are dominated by various trochospiral taxa. The variation in the proportions of benthic foraminiferal morphotypes is suggested to indicate different rates of nutrient supply to (and/or different oxygen levels at) the sea floor during the terminal Cretaceous. Sites with high relative abundances of "buliminid" morphotypes, such as the Tethyan Sites 384 and 465 (mean percentages between 51 and 56%), are suggested to indicate high rates of nutrient supply, whereas the low "buli-minid" abundance at the South Atlantic Site 527 may indicate a low rate of nutrient supply (mean percentage of 15%). The remaining South Atlantic Sites 356, 516, and 525, may be interpreted to represent intermediate rates of nutrient supply (mean "buliminid" percentages between 30 and 43%).

CHRONOLOGY OF LATE NEOGENE ANTARCTIC ICE SHEET VARIATION: GLACIATION, DEGLACIATION, AND ASSOCIATED SEA -LEVEL SIGNATURES

G.S. Wilson (Geology Dept. and Antarctic Research Center, Research School of Earth Sciences, Wellington, New Zealand)

Drillholes in the Ross Sea Sector (CIROS-2, DVDP-10, DVDP-11) and Sirius Group deposits contain direct evidence of Pliocene waning of the Antarctic Ice Sheet. They further record that reglaciation to present day levels did not occur until around 2.5 Ma. The present intensity of glaciation of the Antarctic was probably unequalled prior to the Pliocene.

K/Ar, Ar/Ar, and ^{10}Be methods have been used to date horizons in the CIROS-2 and DVDP-11 cores. These datums allow correct interpretation of the palaeomagnetic stratigraphy. They also provide calibration of diatom biostratigraphy in Antarctic interior basins, thereby dating ice-free events recorded by the presence of diatoms in Sirius Group deposits. The CIROS-2 and DVDP-11 cores record smaller valley-glacier fluctuations in the Pliocene, with major ice sheet growth and grounding in the Ross Sea Region at about 2.5 Ma.

A correlative sea level record from the Wanganui Basin, New Zealand (also presented at this conference) shows 3rd order cycles (Vail, 1990 terminology) that correspond to Antarctic ice sheet waning both in duration and timing. Smaller duration cyclicity has two marked signatures: 1) When the Antarctic ice sheet is present, 5th order glacioeustatic cycles of 100 ky duration are observed. These occur during the latest Miocene and latest Pliocene and Pleistocene; 2) When Antarctica is partially deglaciated, larger cycles of 300+ k.y. duration are observed (4th order ?). These occur during the Early Pliocene.

This correlation of Antarcitc and Wanganui Basin records demonstrates that the observed 3rd and 5th order sea level cycles were glacially driven. 4th order fluctuations are more problematic, but are present only at times of reduced ice volume.

A HIGH-RESOLUTION, SEA-LEVEL RECORD FOR THE LATE NEOGENE FROM WANGANUI BASIN, NEW ZEALAND

G.S. Wilson (Geology Dept. and Antarctic Research Center, Research School of Earth Sciences, Wellington, New Zealand)

Late Neogene sea level fluctuation is recorded by a 5 km thick shelf margin sediment wedge now uplifted in Wanganui Basin, New Zealand. Sedimentary basins at active margins, such as the Wanganui Basin, have the potential to record sea level variation with higher resolution than passive margin basins. This is because higher sediment influx rates can keep pace with the increased basin subsidence. This results in an extended stratigraphic records of fluctuating sea levels.

In the Wanganui Basin sedimentation has kept pace with subsidence to produce a record of dynamic alternation of sea level in the late Neogene. Palaeomagnetic stratigraphy, together with biostratigraphic datums provide a chronology with a resolution of 10 ka for this strata. Two distinctive types of sedimentary cycle are present: A 100-500 m thick coarsening upwards package, often capped by a shell reef facies; and a 20-80 m thick fining upwards package, often with basal and mid cycle shell lags. Both package types are unconformity bounded with the time missing generally being less than the dating resolution. The thicker coarsening upwards cycles are interpreted as shelf margin systems tracts, while the thinner fining upwards cycles are highstand systems tracts.

The latest Miocene (6.5-5.5 Ma) and latest Pliocene (<2.5 Ma) are marked by fining upwards cycles of 100 kyr duration (5th order glacioeustatic cycles of the Vail 1990 scheme). The early Pliocene (5-2.5 Ma), however, is marked by coarsening upwards cycles of 300+ k.y. 3rd order cyclicity is marked in the basin by the change from shelf margin systems tract to highstand systems tract sedimentation of 2-3 m.y. duration.

This variation in sedimentary cycles suggests warmer conditions than present day, with higher sea levels, in the early Pliocene; and conditions in the latest Miocene similar to the latest Pliocene and Pleistocene. The major changes between the sedimentary regimes and the sea level base lines occur at 5.5 Ma and 2.5 Ma. These changes are inflexion points in the 3rd order cyclicity.

THE $\delta^{18}O$ SIGNATURE OF THE NORTH ATLANTIC DEEP WATER DURING THE LAST GLACIAL MAXIMUM, THE YOUNGER DRYAS, AND THE HOLOCENE IN THE NORTHERN EAST ATLANTIC

K. Winn (Geologisch-Paläontologisches Institut, Kiel, Germany), H. Erlenkeuser, L. Labeyrie, and M. Sarnthein

The oxygen isotope records of the benthic foraminifer *Cibicidoides wuellerstorfi* from sediment cores of the East Atlantic illustrate, on a south-north section, that changes of the East Atlantic deep-water distribution pattern in the last 30,000 years.

In the onset of isotope stage 2 (time slice 20-18 ^{14}C-ka), the northern East Atlantic reveals a vertical $\delta^{18}O$ stratification with almost no north-south gradients. Shortly before Termination I, a distinct NADW structure above 3000m water-depth already extends as far south as the Sierra Leone Rise. This pattern continuous in the Older and younger Dryas time slices, with however reduced gradients, a situation similar to the modern time (0-4 ^{14}C-ka). In the early Holocene a NADW water mass is not clearly identified.

DIMORPHISM IN *C. WUELLERSTORFI*: SIGNIFICANCE FOR THE CARBON AND OXYGEN ISOTOPE RECORD

K. Winn (Geologisch-Paläontologisches Institut, Kiel, Germany) and H. Erlenkeuser

Isotope measurements on over 450 pairs of sinistral and dextral specimens of the "epibenthic" foraminifer *Cibicidoides wuellerstorfi* from sediment cores of the Atlantic and Pacific Ocean show that the oxygen and carbon isotope signal of this species is more complex than previously accepted. Variations of more than 0.5‰ were observed in both the $\delta^{18}O$ and $\delta^{13}C$ records.

Although the isotopes of both *C. wuellerstorfi* varieties have no significant offset on the whole, systematic and significant differences of either sign may occur over shorter intervals of the stratigraphic record. In detail, the frequency distribution of the two varieties, bioturbational mixing and environmental factors may exert appreciable influence on the isotopic signal and hence on the finer structures of the isotope stratigraphy derived from *C. wuellerstorfi*.

Generally the isotopic differences are less in glacial stages than in the terminations, and are surprisingly pronounced in some Holocene sections.

A STABLE ISOTOPIC RECORD FROM THE CARIBBEAN: LITTLE ICE AGE TO 1991

A. Winter (Dept. of Marine Sciences, Univ. of Puerto Rico, Mayagüez),
H. Erlenkeuser, R. Zahn, and C. Goenaga

In order to solve questions of climate variability in low latitudes, we need to interpret time series which extend back from the present to a few hundred years. In May, 1991, we retrieved a 160 cm core from a large pinnacle coral of the long-lived species *Montastrea annularis*. This colony is situated on the insular shelf platform in the northeast Caribbean.

Examination of X-radiographs reveals 269 well-distinguishable, high and low density band couplets. However, there is some bio-erosion associated with the last 38 bands. We, therefore, most probably have a continuous record from the Little Ice Age to the present (1760 to 1991). The average distance between HD bands is 6 mm. Small aragonite slabs between HD bands were cut from the coral and homogenized for stable isotopic analysis. Thus, we should obtain a reliable annual record of the environment. Isotopic values ranges for $\delta^{18}O$ are between -3.48 and -4.63 (avg. = -4.16) and $\delta^{13}C$ ranges between -0.03 and -2.17 (avg. = -1.08). These values are very similar to those of other *M. annularis* coral specimens from the Caribbean. There is a good correlation between annual carbon and oxygen values. Both $\delta^{18}O$ and $\delta^{13}C$ become lighter from 1760 to 1991. A major change occurs in $\delta^{18}O$ and $\delta^{13}C$ around the year 1905. Before this time oxygen averages -4.08 and carbon -0.87, afterwards oxygen averages -4.28 and carbon -1.42. The change in the stable isotope values around 1900 may be the result of climatic changes brought about by the industrialization. The oxygen isotopes data indicates that the Caribbean has warmed by about 1°C since the Little Ice Age. Analysis of high-frequency changes in the stable isotope values indicates that there is a relationship between strong ENSO years and fluctuations in the isotopic values. Spectral analysis shows some power at the 6.6 frequency and between 10 and 12-year frequencies. These observations have also been recorded from Pacific corals.

BATHYMETRY OF THE NORTH ATLANTIC OCEAN BETWEEN THE CHARLIE-GIBBS AND JAN MAYEN FRACTURE ZONES DURING THE TERTIARY

C.N. Wold (GEOMAR, Kiel, Germany)

We have used a new paleogeographic model, BALPAL (Balanced Paleogeography), developed by us at GEOMAR to simulate the bathymetry of the northern North Atlantic Ocean during Tertiary times. Bathymetry was reconstructed on a 1 x 1° latitude-longitude grid extending between the present continent-ocean boundaries of Greenland and Europe, and between the Charlie-Gibbs and Jan Mayen Fracture Zones. The model was run at 1 m.y. time intervals starting at the present and ending at the initiation of sea floor spreading between Greenland and Europe (60 Ma).

The model requires several input parameters for each grid cell: 1) an average stratigraphic-lithologic section; 2) the age of the crust; 3) the thermal history; and 4) a eustatic sea level curve. The stratigraphy and lithology of each grid cell was derived from reports of the Deep Sea Drilling Project (DSDP) and Ocean Drilling Project (ODP), from single-channel seismic profiles distributed by the U. S. National Marine Geophysical Data Center (Boulder, Colorado), and from literature sources. Crustal ages of the grid cells were calculated from plate tectonic modelling, where the region was divided into gridded plates that were rotated towards each other at 1 m.y. increments. The crustal age for each grid cell was determined from the age of intersecting magnetic anomalies and the time when overlap with other cells occurred.

To calculate bathymetry several calculations were made for each grid cell. When young sediments were removed from the top of grid cell columns, the remaining sediment thickness was adjusted based on empirical equations for the porosity vs. depth relationship of different sediment lithologies. Thermal subsidence was modelled by changing the mantle density based on average subsidence curves for oceanic lithosphere, adjusted for present lithospheric density. The thickness of the overlying water column was changed according to the eustatic sea level curve. Finally, the elevation of each grid cell was adjusted assuming local isostatic compensation using an Airy-type model.

RESPONSE TO CLIMATIC CHANGES IN THE NORWEGIAN SEA : PLEISTOCENE PLANKTON AND TERRIGENOUS SEDIMENT RECORDS (ODP-LEG 104 SITE 643)

T.C.W. Wolf (GEOMAR, Kiel, Germany), K.-H. Baumann, and J. Thiede

One of the goals of global change research is the study of basic components which control paleoceanographic and paleoclimatic variations and which are able to explain the evolution of oceanographic and climatic changes during the past 1 m.y.. Stable oxygen isotopes (*N. pachyderma* sin.), calcareous nannofossils, anorganic- and organic carbon content and coarse terrigenous particle analyses have been investigated in Pleistocene sediments of ODP LEG 104 Site 643 (Norwegian Sea).

Sampling intervals of 5 to 10 cm have been used to represent time intervals of 2500 years, enabling us to establish a high-resolution oxygen isotope

stratigraphy for the past 1 m.y. which could be used as a standard in the Norwegian Sea.

The calculation of accumulation rates provides the opportunity to reconstruct variations in sediment mass balances which can then be used as recorders of global paleoclimatic and paleoceanographic events. Several periods of abrupt and drastic sediment mass balance variations can be distinguished in the Norwegian Sea and will synthesized as long- and short-term interactions of paleoceanography and paleoclimate.

ANTARCTIC VERSUS ARCTIC EARTH COOLING EVENTS: NEOGENE COARSE TERRIGENOUS PARTICLE SEDIMENTATION (ODP LEGS 104, 105, AND 114)

T.C.W. Wolf (GEOMAR, Kiel, Germany) and J. Thiede

One topic of the global change goals concerns the development and variations of long term cryosphere fluctuations related to earth cooling phases during Cenozoic times. Therefore, one has to compare the data of both the northern and the southern hemispheres.

Our objective is to draw attention to the coarse terrigenous sedimentation in terms of relative particle abundance. These data are able to document that terrigenous particle events can be used as an indicator of ice-rafting and subsequently as a recorder of global cooling events.

Sediment samples recovered through the Ocean Drilling Program in both high northern and southern latitudes have provided us with much more consistent knowledge of the occurrence and timing of coarse terrigenous particle input in deep-sea basins near polar fronts. The data of recent studies of coarse fraction particles on sediment samples from ODP Leg 104 Site 642 and Site 643, and ODP Leg 105 Site 646 are compared with published data of ODP Leg 114 Site 699 A and Site 701 (Warnke and Allen, 1991; Allen and Warnke, 1991) for the past 20 my.

Three periods of Neogene coarse terrigenous events can be distinguished in both hemispheres. Around 14 Ma smaller events are documented at Site 699 and at Site 642 and 643. A second period is revealed around 9 to 8 Ma at Site 701, 646, 643, and 642. A third period starts around 6 Ma at all five sites. Surprisingly, the terrigenous events appear to have occurred nearly simultaneously in both hemispheres. Furthermore it seems to be that this signal is a unique tool for gaining a better understanding of global earth cooling events.

Allen, C.P. and Warnke, D.A. (1991): History of ice rafting at Leg 114 sites, subantarctic/South Atlantic.- In Ciesielski P.F., Kristoffersen, Y., et al., Proc. ODP, Sci. Results, 114: College Station, TX (Ocean Drilling Program), 599-608.

Warnke, D.A. and Allen, C.P. (1991): Ice rafting, glacial-marine sediments, and siliceous oozes: South Atlantic/ subarctic Ocean.- In Ciesielski P.F., Kristoffersen, Y., et al., Proc. ODP, Sci. Results, 114: College Station, TX (Ocean Drilling Program), 589-598.

PLIOCENE PALEOTEMPERATURE RECONSTRUCTION FOR THE SOUTHERN NORTH SEA BASED ON OSTRACODA

A.M. Wood (Institute of Earth Studies, Univ. of Wales, Aberystwyth, UK), R.C. Whatley, and T.I. Cronin

A recent NE Atlantic database established on 78 sites covering an area from the Niger Delta to the Barents Sea and 32677 individuals belonging to 73 genera has been constructed. Using both quantitative (province boundary classification and faunal clustering on the basis of first and last occurrences) and qualitative methods (Q- and R-factor analyses), Wood & Whatley (in prep) recognized ten discreet ostracod he faunal provinces on the NE Atlantic continental shelf. The verification of ostracod provincialism, at both specific and generic levels, greatly enhances their use as proxy data in the paleoenvironmental reconstructions of the North Sea Neogene (ca. 5.2-1.6 Ma).

Neogene ostracod assemblages from both marine and estuarine sediments were analyzed from East Anglia and the southern central region of the Netherlands. A dissimilarity coefficient, the Square Cord Distance, was used employing 73, 59 and 41 genera in order to identify the presence of provincial level affinities between Recent and Neogene ostracod assemblages.

Although problems have been encountered when using Recent monotypic (within the area) genera the results indicate:

i) In the Upper Miocene - lowest Pliocene a period of relative cooling occurred.

ii) Throughout the Lower to mid-Pliocene, Mediterranean/Morrocan provincial conditions prevailed.

iii) At approximately 2.4 Ma, an hiatus occurs both in the Netherlands and East Anglia, after which a true Norwegian provincial fauna becomes established.

iv) Although no data are available for the interval 2.4-1.8 Ma, between 1.8 and 1.6 Ma a typical Norwegian provincial fauna is again established in the area.

GREENLAND-SCOTLAND RIDGE SUBSIDENCE: A POSSIBLE LINK TO NEOGENE DEEP-WATER CIRCULATION PATTERNS AND CLIMATE CHANGE

J.D. Wright (Lamont-Doherty Geolological Observatory, Palisades, NY, USA) and K.G. Miller

The middle Miocene oxygen isotope increase (15 to 12.5 Ma) and Northern Hemisphere glaciation (NHG) (3 to 2.5 Ma) were accompanied by large deep-water circulation changes. Carbon-isotope, geologic, and seismic evidence suggest that Northern Component Water (NCW, analogous to NADW) production was high during the intervals which immediately preceded these climate transitions (~20 to 16 Ma and 4 to 3 Ma) and were times of unusual warmth. NCW flux decreased during the middle Miocene oxygen isotope increase and NHG.

Most hypotheses attribute Neogene climate changes to tectonic reorganization (e.g., Greenland-Scotland Ridge (GSR) subsidence, Drake Passage opening, Panamanian Isthmus closure, plateau uplift). These tectonic changes affected either: 1) the chemical composition of the oceans and atmosphere; or 2) poleward heat transport through surface and deep-water currents. Based on the importance of NADW to modern, late Pleistocene climate changes, we postulate that the NCW decreases from 15 to 12 Ma and 3 to 2.5 Ma were the catalyst for large-scale climate reorganizations.

We have reinterpreted the subsidence history of the GSR and find evidence for interruptions at ~15 and ~3 Ma in the long-term thermal subsidence. The topography of Iceland and bathymetry of the Reykjanes Ridge (RR) show at least two paired vertical offsets. These offsets have greater than 500 m relief and are oriented parallel to the Mid-Atlantic Ridge axis. We postulate that these vertical scarps originated during events of excess volcanism associated with the Icelandic Hot Spot. Volcanic events on Iceland should affect the RR and GSR as well. The vertical scarps along the RR resulted from thermal uplift centered on Iceland. The amplitude of the vertical offsets diminishes to the southwest with distance from Iceland. Heat flow is low along the GSR; therefore, we postulate that the GSR response was flexural not thermal.

Radiometric dates on Iceland lava flows and the magnetic anomalies along the Reykjanes Ridge constrain age of the middle Miocene vertical offsets. K-Ar ages indicate that excess volcanism occurred between 15.5 and 12.5 Ma. This agrees with magnetic anomaly identification which indicate that uplift occurred between Chrons C5B to C5A (~15.5 to 12 Ma). The Pliocene offsets are constrained by correlation to Anomalies 3 to 2A, indicating that uplift occurred between 4.0 and 2.4 Ma. In each case, reduced NCW production correlated with inferred GSR uplift, each of which preceded a major climate change.

TRANSIENT BEHAVIOR OF THE DEEP-OCEAN CIRCULATION AND TRACER FIELDS DURING THE YOUNGER DRYAS

D.G. Wright (Bedford Institute of Oceanography, Dartmouth, NS, Canada), T.F. Stocker, and W. S. Broecker

A 3-basin, latitude depth ocean model is used to simulate the deep circulation of the world ocean and its variability (Stocker et al., 1992, J. Climate). Using present-day surface forcing, sinking occurs in the North Atlantic and Southern Ocean and realistic temperature and salinity structures are obtained in the Atlantic, Pacific and Indian oceans. "Color" tracers and radiocarbon are used to identify the composition of deep water masses and associated renewal time scales. A realistic simulation of these characteristics is obtained.

Under mixed boundary conditions this steady state is perturbed by a surface freshwater flux following the discharge history of Fairbanks (1990). The first meltwater peak shuts off the conveyor belt within a few decades: NADW is no longer exported into the world ocean and the meridional heat flux in the Atlantic is greatly reduced. The conveyor belt circulation turns on again before the start of the second, weaker melt peak. In contrast to the first peak, the second melting event does not shut off the deep circulation but merely slows it down temporarily. The dependence of the nature and timing of the ocean's transient behavior on various parameters and the initial steady state is presented.

Inorganic and organic carbon cycle models will be coupled to the circulation model to investigate the effect of rapid changes of the thermohaline circulation on the pCO_2 of the atmosphere and results will be discussed.

LOW MAGNESIAN CALCITIC TESTS OF BENTHIC FORAMINIFERA CHEMICALLY MIRROR MORPHOLOGICAL DEFORMATIONS

V. Yanko (Dept. of Geophysics and Planetary Sciences, Tel Aviv Univ., Israel) and J. Kronfeld

Haifa Bay is an intensively industrialized region that receives a wide variety of pollutant inputs. It is alone among the polluted coastal regions of Israel in that its sediments are significantly enriched in a variety of toxic and biologically active trace metals.

Grab samples and box cores were taken from various stations in the bay to study the benthic foraminifera. As in other areas, the dominant foraminifera are *Ammonia tepida Cushman, Porosononion martkobi mediterranicus Yanko,* and *Triloculina marioni Shlumberger.* However, their test sizes are characteristically stunted. Moreover, a variety of morphological abnormalities are frequently encountered, which range from minor to the grotesque. These are similar to the deformities encountered by the senior author in the trace-contaminated Odessa Bay of the Black Sea. At least 10 of the foraminiferal species from 7 families populating Haifa Bay evince significant deformations.

Foraminiferal species produce either low or high magnesian calcite. The concentrations of the major elements were measured using SEM with attached EDS in profile across each individual test. It was found that the deformed specimens of the low-magnesian calcites can yield highly variable results, specifically for Mg and S, between specimens, as well as within a single shell. The Mg, for example can rise from approximately 0.1% to as high as 2.9%. The stunted but non-deformed tests of the low-magnesian calcite species do not exhibit such variability, nor does the high-magnesian calcitic species. It is proposed that raised Mg concentrations reflect a weakening of the biologic barrier that differentiates between the bivalent cations in the environment. Poisoning by trace metals cripples the organisms' ability to selectively incorporate Ca against the high Mg/Ca gradient in seawater. Likewise in seawater there is a very high SO_4/CO_3 ratio. It is tentatively proposed that the elevated sulfur represents sulfur in the form of SO_3 substituting structurally for CO_3.

PLEISTOCENE AND HOLOCENE SEA LEVEL CHANGES IN THE BLACK SEA AND THE CASPIAN SEA

V. Yanko (Dept. of Geophysics and Planetary Sciences, Tel Aviv Univ., Israel)

For the last 20 years an extensive study was carried out in conjunction with the Geological Survey of the U.S.S.R to reconstruct the rhythmic oceanic interplay between the Mediterranean, Black and Caspian Seas during the Quaternary. To this end almost 30,000 geological samples were collected from onshore and offshore sites. Benthic foraminifera were used to determine ecological conditions. A spectrum of fifty environments (such as deltas, open and closed lagoons, bays, inner and outer shelf, etc.) were defined. As the climate changed the environment at a site also changed. By studying the facies changes, reflected in the changing ecological environments, transgressive and regressive sea levels were identified. Chronological controls were employed to establish the precise regional stratigraphy. Radiocarbon and $^{230}Th/^{234}U$ methods were used along with paleomagnetism as well as archaeological controls.

Pleistocene and Holocene benthic foraminifera are represented by 165 species. Today 104 of these have resettled into the present Black Sea. Only 18 species, mostly relicts, are found at present in the Caspian Sea. During interglacials, transgressive seas allowed for the migration of Mediterranean Fauna into the Black Sea. During glacial times the connection was stopped. The interconnection between the Black and Caspian Seas responded oppositely. During glacial times, precipitation drainage into the Caspian Sea resulted in flow from the Caspian to the Black Sea. This connection terminated during interglacial times.

A synthesis of our results shows that connections between the Mediterranean and Black seas occurred during the Pleistocene at 530 Ky, 400 Ky, 320 Ky, 130 Ky, 80 Ky B.P. During the Holocene interconnection was established approximately 8 Ky B.P. Connection between the Black and Caspian Seas existed prior to 760 Ky B.P. and continued into the Late Pleistocene.

RECONSTRUCTION OF GLACIAL/HOLOCENE CHANGES IN PARTICLE RAIN RATE IN THE SOUTH INDIAN OCEAN AS RECORDED BY ^{231}Pa, ^{230}Th AND U IN SEDIMENTS

E.F. Yu (Woods Hole Oceanographic Institution, Woods Hole, MA ,USA), M.P. Bacon, and R. Francois

Holocene and Last Glacial Maximum (LGM) sections of cores forming a north-south transect across the present Subtropical Convergence (STC), Subantarctic Front (SAF, at ≈46°S), and Polar Front Zone (PFZ, at ≈52°S) in the South Indian Ocean were analyzed for ^{230}Th, U isotopes and ^{231}Pa to reconstruct changes in the flux of opal, carbonate, organic carbon and terrigenous matter. Results from the Holocene show a maximum in ^{230}Th-normalized opal flux in the region of the PFZ. North of the present PFZ, opal flux is lower than immediately south of the PFZ. There are also remarkably high ^{231}Pa/^{230}Th ratios and authigenic uranium contents at the PFZ; The high ^{231}Pa/^{230}Th ratios reflect enhanced scavening at the PFZ; higher authigenic U concentrations imply more reducing conditions in the underlying sediments. These latter two observations are consistent with the higher opal rain rates at PFZ deduced from ^{230}Th-normalization. Data from the LGM section show similar latitudinal features. Variations in the ^{231}Pa/^{230}Th ratios and authigenic U contents are again found to be correlated with variations in normalized opal flux at the PFZ. The data also suggest a higher opal flux of sediments north of PFZ during the LGM, presumably reflecting higher primary production in the overlying water. However, a decreased opal flux is found for sediments south of the PFZ consistent with recently published observation by Mortlock and others. In contrast to the Holocene data, excess ^{231}Pa/^{230}Th ratio and authigenic U for the LGM show maximum values might have occurred slightly south of the present polar front. This study demonstrates the use of ^{231}Pa/^{230}Th ratios as an indicator of paleoflux and paleoproductivity.

HIGH-RESOLUTION ISOTOPIC RECORDS FROM ACROSS THE EOCENE/OLIGOCENE BOUNDARY: THE SEARCH FOR MILANKOVITCH PERIODICITY

J.C. Zachos (Univ. of California, Santa Cruz, USA), T.M. Quinn, and K.C. Lohmann

Recent investigations of Paleogene sequences recovered from the Southern Ocean support the hypothesis that ice sheets on Antarctica expanded significantly during the earliest Oligocene. In this light, it is reasonable to assume that Oligocene continental ice sheets may have varied in response to the same orbital forcing parameters that influenced climate and ice sheets during the Neogene. However, Milankovitch climate cycles have yet to be identified in Paleogene marine sequences. Few studies have sampled with sufficient resolution to identify high-frequency geochemical or sedimentological variations. As a result, the effects of orbital forcing on Paleogene climate are still essentially unknown.

We have carried out a stable carbon and oxygen isotope investigation of planktonic and benthic foraminifers sampled at high resolution (10^4 yr) from the two Eocene/ Oligocene pelagic sequences, a mid-latitude site, 522, in the South Atlantic Ocean, and a high latitude site 748, in the southern Indian Ocean. To date, our investigation has not recovered a Milankovitch periodicity in either carbon or oxygen isotope records in the time prior to, during, or after the glacial maximum, indicating that the Antarctic ice sheets were not noticeably responding to orbital forcing during this interval of time. Lack of evidence for external forcing suggests that this climatic transition represents some type of threshold event driven by processes internal to the earth. Carbon isotope and sedimentological records suggest that the early Oligocene glacial maximum was accompanied by a substantial, but brief increase in global marine productivity. We speculate that sudden intensification of ocean and atmosphere circulation may have triggered this productivity pulse.

NORTHEASTERN ATLANTIC BOTTOM WATERS DURING THE LATE MIOCENE AND EARLY PLIOCENE

J. Zhang (Dept. of Earth Sciences, Dalhousie Univ., Halifax, Nova Scotia, Canada) and D.B. Scott

Benthic foraminifera greater than 63 μm from 11 northeastern Atlantic DSDP/ODP Sites (547A, water depth 3938m; 544A, 3581m; 136, 4169m; 334, 2619m; 558A, 3754m; 637A, 5307m; 608, 3526m; 410, 2975m; 119, 4447m; 610, 2417m; and 141, 4148m) have been examined to determine the bottom-water changes during the late Miocene and the early Pliocene. The benthic foraminiferal assemblages indicate that the paleo-environment of the Mid-Atlantic Ridge was different from the eastern Northeast Atlantic basin. The west flank of the Mid-Atlantic Ridge is characterized by dominant *Globocassidulina subglobosa*, *Epsitominella exigua*,and *Eponides weddellensis* throughout the late Miocene and the early Pliocene (Sites 410 and 558A), indicating a consistent control by North Atlantic Deep Water (NADW), although it may be slightly influenced by Antarctic Bottom Water (AABW). The eastern basin seems to be more complicated. High proportions of *Nuttallides umbonifera* (10-50% of the total benthic fauna) at Sites 637A, 608, 5447A, and 544A shows intensifying of AABW in the eastern basin during the Messinian stage, which may be associated with the cessation of the Mediterranean Outflow Water (MOW) entering the North Atlantic Ocean or global paleoclimatic cooling. During the

early Pliocene, the eastern basin appears to be dominated by a mixed-water mass of NADW, AABW, and MOW. The MOW may be indicated by *Bolivina* sp.A, which is a very tiny species (63-100 µm) with a quadrate periphery and rough surface of test, and restricted to the area near the Strait of Gibraltar (Sites 547A, 544A, and 637A). High proportions of *N. umbonifera* (30-40%) also suggest that the eastern basin was distinctly controlled by the Antarctic Bottom Water during the early and middle Miocene (Site 136).

DIATOMS - TOOLS FOR QUATERNARY PALEOENVIRONMENTAL RECONSTRUCTIONS IN THE SOUTHERN OCEAN

U. Zielinski (Alfred Wegener Institute, Bremerhaven, Germany) and R. Gersonde

As a base for paleoenvironmental reconstructions in the late Quaternary Southern Ocean sediment record a diatom reference data set was established, which includes species counts of 174 surface samples. The sample set covers an area from the southern Weddell Sea to the subtropical warm water region.

For the statistical treatment 36 surface samples were selected. As a large portion of the counted assemblages is dominated by one taxon (*Nitzschia kerguelensis*) it was inevitable to transform the original data into a classification system with 4 abundance classes ("ranking") after Pichon et al. (1987). A Q-mode factor analysis according to the method of Imbrie and Kipp (1971) of the ranked data set results in 4 factors. The faunal factors were related to modern day austral summer surface-water temperature, salinity and phosphate concentration by multivariate regression analysis. The resulting transfer functions have low standard errors of estimate, the correlation coefficients for temperature and salinity are > 0.98, and the value for the phosphate concentration reaches 0.96.

The distribution of "sea-ice"-algae (*Nitzschia curta* and *N. cylindrus*) in surface sediments shows a close relation with sea-ice distribution. Highest percentages (20% - 50% of total assemblages) occur in the coastal areas of the Weddell Basin, which are influenced during most of the year by sea ice. North of the maximum winter sea-ice distribution the amounts drop to insignificant values below 1%. The distribution and abundance pattern of the sea-ice indicator taxa does not depend on the annual duration of seasonal ice coverage, but on the presence of sea ice over a multi-year time interval. The distribution of *Eucampia antarctica* does not display a relationship with sea ice. Significant amounts (5 - 15%) concentrate in the area north of the winter sea-ice distribution in a region, which is known as melt-down area of icebergs. This suggests that *E. antarctica* is neither a taxon related to sea ice, nor strongly dependent on water temperature. It is speculated that the occurrence pattern of *E. antarctica* which reaches up to 40% of the total assemblages during glacial time periods is mainly triggered by low salinity conditions.

ENVIRONMENTAL AND CLIMATIC INTERPRETATION OF POLLEN, SPORES AND DINOFLAGELLATE-CYSTS ASSOCIATIONS DURING THE PAST 15,000 YEARS IN THE EASTERN MEDITERRANEAN

C.A.F. Zonneveld (Palaeobotany and Palynology Lab, Univ. of Utrecht, The Netherlands)

High-resolution analysis of changes in the pollen, spores, and dinoflagellate-cyst content in the last 15,000 years in three cores in the Eastern Mediterranean have been carried out. Preliminary results of both the marine and continental fossil records will be presented and are interpreted in terms of environmental and climatic changes.

Two cores were drilled south and northwest of Crete at a water depth of 707m and 607m, respectively. The third core was drilled in the Adriatic Sea at a water depth of 1234m. The fossil record of all cores is dominated by a dinoflagellate-cyst association, characteristic for outer neritic to oceanic environments and by the wind-dispersed pollen of *Pinus* and *Quercus*. Major changes in pollen, spores, and dinoflagellate-cyst associations, coincide with the first sapropelic layer in the Eastern Mediterranean. In this layer the dinoflagellate-cyst association is dominated by species characteristic for neritic environments. Quantitatively, however, no decrease in amounts of outer neritic and oceanic species is observed. The amount of pollen types increases remarkably in the sapropel. Changes in pollen associations indicate increased runoff during this interval.

Furthermore a less-pronounced temperature change is observed. Dinoflagellate-cysts characteristic for temperate to cold water masses disappear following the latest glacial maximum and have a short comeback during the Younger Dryas cold episode.

ABSTRACTS

WORKSHOP

Sediment Waves and Sediment Drifts:
Monitors of Global Change

FEATURES OF NORTH ATLANTIC DEEP-WATER CIRCULATION SINCE THE PENULTIMATE GLACIATION, AS INDICATED BY WESTERN BOUNDARY UNDERCURRENT ACTIVITY ON THE BLAKE OUTER RIDGE, WESTERN NORTH ATLANTIC

B.J. Haskell (Limnological Research Center, Univ. of Minnesota, USA)

A record of the grain size of the detrital silt fraction extending back to isotope stage 6 was generated for core CH89-1P from 3180 m on the crest of the Blake Outer Ridge (BOR), western North Atlantic. The mean grain size is interpreted as primarily reflecting site-specific relative strength and position of the Western Boundary Undercurrent (WBUC) relating to the hydrographic characteristics and the rate of North Atlantic Deep-Water production. Grain-size patterns at site 1P reveal a broad pattern of maxima centered on isotope stages 1, 3, 5, and 6.5, and minima centered on stages 2, 4, 6.4, and possibly 6.6. The absolute grain-size values, however, do not consistently relate to absolute $\delta^{18}O$ in planktonic foraminifera throughout the record. This suggests that slightly different patterns of WBUC circulation may be established during different generations of equivalent climatic conditions, although there is also the possibility of long-term, source-related, non-hydrodynamic influence upon grain size.

The CH89-1P record can be compared with similar records in cores from 2950 m (CH84-7P) and 4400 m (CH84-4P) on the BOR (Johnson et al., *Paleoceanography*, 3, 191-207, 1988) for the last 50 ky. Grain size in both 1P and 7P is highly variable during stage 3 and shows a net decrease to intermediate values found through much of stages 1 and 2. Grain size at site 4P on the lower part of the ridge also decreases from stage 3 to stage 2 but is coarsest during the Holocene. These results suggest that on all parts of the ridge general WBUC circulation intensity was weakest during stage 2. Considered in terms of intracore variability for the whole of the last 50 ky, the biggest change during the post-glacial circulation increase took place on the lower part of the ridge. Conditions during stage 3 on the other hand, appear to have led to fluctuating production of upper NADW, which is generally enhanced relative to the stage 1 interglacial and may be related to deep-water source area configurations particular to conditions of intermediate glaciation.

SEDIMENT DISTRIBUTIONS, ACCUMULATION RATES AND HIATUSES IN THE INDIAN OCEAN THROUGH THE CENOZOIC: THE ROLE OF EVOLVING BATHYMETRY

R.B. Kidd (Univ. of Wales, Cardiff,UK), T.A.Davies, A.T.S.Ramsay, J.V.Royer, and the P.A.L.I.O.S. Team

Over one hundred ODP and DSDP drill sites in the Indian Ocean potentially provide a precise record of changing sediment distributions, and thus climate and circulation, through Cenozoic time. The Paleoceanographic Indian Ocean Synthesis Project (PALIOS) has developed common litho- and chrono-stratigraphies for the ODP and DSDP sites through low to high latitudes and has constructed new paleobathymetric reconstructions on which to plot sediment parameters including accumulation rates and hiatus occurrence. Map reconstructions will be displayed at ICP IV for key paleoceanographic time intervals including Early/Middle Miocene, Eocene/Oligocene boundary, Middle Miocene and Miocene/Pliocene boundary. Early Miocene accumulation rates were low as carbonate sedimentation became widespread initially and then became restricted to high accumulation rate areas on western Indian Ocean plateaus and ridges after the mid-Miocene rapid growth of the Antarctic ice cap.

Siliceous sedimentation first appeared in high latitudes in the Early Oligocene and accumulation rates substantially increased in the Late Miocene.

The times of widespread hiatuses were also periods of generally low accumulation rates suggesting that the hiatuses do not represent simply erosion, redistribution and deposition elsewhere.

THE RECORD OF BOTTOM CURRENT SPEEDS IN DEEP-SEA SEDIMENTS

I.N. McCave (Dept. of Earth Sciences, Univ. of Cambridge, UK)

The depositional regime, particularly the current speed, exerts a strong control on the characteristics of the deposit. The bottom boundary layer filters aspects of the input signal from vertical settling and horizontal flux in nepheloid layers. Fabric is dominated by bioturbation so currents cannot be inferred from sedimentary structures. Deposition is permitted when for a particle (usually aggregate) settling velocity w_s the bottom stress is below a critical value T_C. Under high stress deposition of clay is suppressed and a coarser deposit forms. Deposition from suspension is dominant with little bed-load transport. All deep-sea currents fluctuate and regions of large speed variation in days to weeks are called "stormy". We cannot yet distinguish regions with different time scales of fluctuation by their sediments alone. Nice modern regional examples of high speed are the Nova Scotian Rise, northeastern U.S.A. margin and the Argentine Basin. The parameters used to delineate the currents there were silt mode size and peak height and terrigenous silt mean size. Wide spectrum grain-size analyses and experimental data show that fine silt ($\delta < 10$ μm) behaves in a cohesive manner similar to clay while coarse silt ($\delta = 10$ to 63 μm) is nearly non-cohesive. Therefore, the percentage of the <63 μm fraction that is coarse silt is a useful parameter. The coarse fraction >63 μm is almost always foraminiferal, ice-rafted or in a gravity flow deposit. There is little quartz sand transport by deep-sea currents because speeds (at 1 mab) greater than 30 cm/s are required; these are rare and would not yield much bed-load flux.

A difficulty with evaluation of current speeds from sediment size is the influence of provenance. A record from the S. Brazil Basin, showing size fluctuations at ~40 and ~20 ka at a site far from source, is argued to demonstrate current speed variation. The delivery from continents to the continental rise involves erosion and mixing of sediment populations so that a clear glacial/interglacial signal is unlikely from gravity flows. It does arise from ice-rafting, however, and the extraction of signals from sediments affected by ice-rafting currents, and biological productivity is difficult. Recent attempts to isolate current signals in mid- to late-Pleistocene sediments from Vema Channel, the eastern USA margin, and N.E. Atlantic drifts will be discussed. The picture is not clearly one of decreased glacial current speeds. The relationship between local current speed and the vigor of ocean circulation is also debatable.

SUSPENDED SEDIMENT TRANSPORT IN WEDDELL SEA BOTTOM WATER

C.J. Pudsey (British Antarctic Survey, Cambridge, UK) and M.E. Barber

Hemipelagic sediments in the northern Weddell Sea show grain-size changes down core which are interpreted to reflect changes in speed of the transporting current. We present data on suspended sediment from two areas, (i) the NW Weddell Sea slope which is an area of bottom water formation and a present -day sediment source, (ii) Jane Basin, a lower-energy area and a present-day sediment sink. The deep nepheloid layer is up to 200 m thick, and suspended sediment concentration is as high as 3 mg/liter. Transmissivity and temperature profiles show evidence for intermediate nepheloid layers in areas of water-mass mixing over the slope. The two sources of suspended particles are settling from the surface water which supplies mainly biogenic silica (diatoms), and erosion from the seabed which supplies terrigenous grains and fragmented diatoms. Size distributions of suspended particles show a relationship to water depth, with larger particles in suspension higher on the slope. Similarly, surface sediment samples are dominated by sand on the upper slope, medium slit on the mid slope and fine silt and clay on the lower slope and rise.

At glacial maximum with ice grounded to the shelf edge and abundant unsorted sediment being dumped on the slope, much more material was available for resuspension: however, deep circulation was slower and "glacial bottom water" carried only the finest size fraction.

HIGH -RESOLUTION MAGNETOSTRATIGRAPHY OF QUATERNARY SEDIMENTS FROM THE SOUTHERN OCEAN

C.J. Pudsey (British Antarctic Survey, Cambridge, UK) and N. Hamilton

Sediment cores from the northern Weddell Sea and southern Scotia Sea (60° to 64° S) have been measured on a whole-core cryogenic magnetometer at 2 cm sampling interval. Core sections have been AF demagnetized in steps up to 40 mT. We present data on inclination, declination and intensity, plus magnetic susceptibility. The cores are all assigned to the Brunhes normal polarity chron, with mainly high negative inclinations (-70° to -85°). The remanence shows good stability, with demagnetized intensities of 3×10^{-8} to 2×10^{-5} emu/cc away from reversals. Most cores record a brief reversed event or excursion (reversal in inclination, swing in declination, drop in intensity) just below a biostratigraphic datum correlated with the Last Glacial Maximum. The longer cores record additional older reversals. Short-period (1,000 to 5,000 years) variations in inclination and declination are also seen throughout all cores and are attributed to paleosecular variations in the Earth's field. Some of the larger secular variations can be correlated from core to core.

This detailed magnetostratigraphy permits relative dating of textural, mineralogical and chemical changes downcore. Absolute dating of reversals may be possible by radiometric methods.

ORBITAL-CLIMATIC INFLUENCES ON BOTTOM-CURRENT, ENHANCED SEDIMENTATION ON FENI DRIFT (DSDP SITE 610), N.E. ATLANTIC, DURING THE MID-PLEISTOCENE

S.G. Robinson (Dept. of Earth Sciences, Univ. of Cambridge, UK) and I.N. McCave

Feni Drift was deposited along the northwestern flank of Rockall Trough in the Northeast Atlantic under the influence of geostrophic bottom currents which, today, are formed by Norwegian Sea Overflow Water, strengthened by recirculating North Atlantic Deep Water. Dilute Antarctic Bottom Water also bathes the lower flanks of the drift (>2500 mbsl). DSDP Site 610 was drilled in a sediment wave field on the surface of Feni Drift (2417 mbsl). The sediments recovered, however, are typically pelagic, preserving, with high-resolution, a Quaternary record of orbitally modulated ice-rafting and biogenic productivity cycles, but apparantly little evidence of current affected deposition.

From particle size and compositional analysis, both of the biogenic and lithogenic fractions of samples taken at ca. 2.5 ky intervals from Hole 610A, between 0.5 - 1.2 My BP, we have derived indices of bottom current enhanced silt deposition, and compared these with records of IRD and bioproductivity (foram and coccolith) fluxes. Cross-spectral estimates of these records and variations in an index of Northern Hemisphere ice-volume were then made.

Both total carbonate and noncarbonate mass accumulation rate (MAR) variations are highly coherent (0.75 - 0.95) and almost perfectly in phase with ice-volume fluctuations (IVFs) at all of the Milankovitch (ETP) frequencies. This reflects the reciprocal relationship between IRD influx and coccolith productivity in response to glacial cycles. Cross-spectra of IRD Sand MAR and coccolith MAR V Ice Volume confirm this relationship, though IRD responds only weakly to obliquity (41 ky) forcing, and coccolith MAR is not affected at all by eccentricity (100 ky) variations. Foram MAR varies little in response to IVFs, its spectrum containing only a minor 41 ky peak. In contrast, variations in bottom-current, enhanced silt deposition display excellent phase and coherency agreement with IVFs at all ETP frequencies, and most of the power on this spectrum is concentrated at these frequencies. Enhancement of silt deposition by bottom currents appears to be more pronounced during glacials at this site. However, this does not necessarily imply that currents are stronger here during glacials than they are during interglacials.

HEINRICH LAYERS AND HIGH-RESOLUTION STRATIGRAPHY IN THE EASTERN NORTH ATLANTIC OCEAN

Tj.C.E. van Weering (NIOZ, Texel, The Netherlands), L. Labeyrie, F. Grousset, E. Cortijo, H. Leclaire, J.-Y. Reynaud, L. Vidal, S.v.d.Gaast, G. Klaver, and T. van Meerten

Heinrich events, layers with highly increased levels of ice-rafted detritus (IRD), recently have been shown to occur over almost the entire North Atlantic Ocean ref 1, 2, 3. Available results indicate that the upper two Heinrich layers (H1, H2) have IRD contents derived from Canada. By contrast, H3 is characterized by components of Fennoscandian origin. H4 and H5 again have a Canadian affinity and in turn H6 has again a northern European source. At ODP site 609 Heinrich layers have a near absence of planktonic foraminifera, possibly caused by dilution with rapidly accumulating debris or by reduction of surface water productivity.

Here we provide a comparison of site 609 results with the Heinrich layer distribution in sediment cores from the eastern and western North Atlantic Ocean, spanning the last 250ky. Most of the events can be traced in the cores, and show that Heinrich events are associated with light ^{18}O anomalies in *N. pachyderma* (s) and peaks in magnetic susceptibility.

The relative amplitude of the IRD peaks, their composition and geochemical characteristics permit separation of the melting events associated with the Laurentide and European ice sheets.

High resolution stratigraphy and AMS dating for H1, H2 and H3 are provided to further constrain ages and duration of the events.

References: 1) Heinrich, H., 1988, Quat. Res., 29: 143-152. 2) Broecker, W., et al., 1992, Climate dynamics 6: 265-273. 3) Bond, G., et al., 1992, Nature (submitted).

THE CANARY BASIN - BUDGETS FOR SEDIMENT TRANSPORT AND RELATIONASHIP TO SEA-LEVEL CHANGE

P.P.E. Weaver (Institute of Oceanographic Sciences, Godalming, Surrey, UK) and M. Dekker-Niewold

Mass wasting of hundreds of cubic kilometres of sediment in single events is a common phenomenon in the Canary Basin of NW Africa. The sediments are transported as debris flows, which deposit on the continental slope, and turbidity currents which deposit on the Madeira Abyssal Plain. Recent data has shown a connection between the two mechanisms, suggesting they flow as different phases from common source areas. These source areas have been determined for a large number of turbidites on the Abyssal Plain by sedimentological and geochemical means and by mapping one of the most recent flows. The Canary Islands and upwelling centers along the African margin are the most common sources. A regular pattern of sedimentation occurs on the plain, which suggests the turbidites (and debris flows) are initiated around the time of sea-level change - both rising and falling - although only one turbidity current is generated at each change. Analysis of microfossil mixtures in the turbidites shows that they each incorporate a few hundreds of thousands of years of material, which is equivalent to erosion of 50-100 meters depth of sediment in the source areas. Since the volumes of each turbidite have been calculated, the areas eroded to generate each flow can also be estimated as a few thousand square kilometres. Thus, it is now possible to model the Canary Basin in terms of budgets of sediment erosion and transport from shallow to deep sea. The regions susceptible to erosion have been identified, and these areas of a few thousand km^2 are eroded to depths of 50-100 m with a frequency related to sea-level change. The eroded material is deposited downslope as debris flows, and on the Abyssal Plain, as large-volume turbidites.

CHANNEL-LEVEE SYSTEMS EAST OF CRARY FAN, ANTARCTICA

M. Weber (Alfred Wegener Institute, Bremerhaven, Germany) and G. Kuhn

On the continental margin of the southeastern Weddell Sea, several channel-levee systems can be traced east of Crary Fan. Bathymetric investigations reveal SW-NE striking ridges up to 300 m in height with southeastern situated channels, respectively. These structures occur on a terrace of the continental slope in water depth of 2000-3000 m. Subbottom profiling with PARASOUND and 3.5 kHz characterize the ridges by a deep acoustic penetration (up to 80 m) and numerous parallel to subparallel subbottom reflectors, whereas the channels show a hard surface reflector with rather no acoustic penetration. Sedimentological studies and ^{14}C AMS-dating on gravity corers indicate predominantly micro-laminated mud interacting with cross stratified coarse-siltic sediments on the ridges during the last glacial maximum. In Holocene time, the sediments are dominated by bioturbated mud.

The sedimentary facies as well as the subbottom profiling seem to fit the concept of contour currents shaping the continental slope. These bottom currents are channelized within the channels. Due to coriolis force, micro-laminated mud is accumulated on the western channel flank (=sedimentary ridge) as a levee deposit with high sedimentation rates. Turbidity currents disrupt the contour currents in unequal intervals and lead to cross stratified spill-over turbidites on the ridges. These processes of an active fan growth east of Crary Fan are concentrated on glacial times, as indicated by ^{14}C-AMS-dating, whereas in interglacial times, the fan is sediment-starved and prevailed by bioturbated mud.

SEDIMENTS OF THE ICELAND FAROE RIDGE: OVERFLOW CIRCULATION CONTROLING BEDFORM PATTERNS

F. Werner (Geologisch-Paläontologisches Institut, Kiel, Germany), W. Dorn, and D. Milkert

The overflow circulation entering the North Atlantic via Iceland Faroe ridge and the Faroe Channels give rise to a multitude of sorting effects and bedform formation which raises the following background questions: 1) how "good" is the coincidence between the oceanographically and sedimentologically determined qualities of flow direction and power? 2) Should it be possible to infer bed load transport rates from comparison of temporally differing, sonographically surveyed bedform patterns? 3) Does a main sediment stream exist on the southern slope and, if so, which is its exact geographic position?

A slope-parallel channel system on the southern slope of the ridge with overflow current-controlled, asymmetrical sediment fillings permits study of the development of the overflow currents by means of sediment cores taken from opposite channel flanks. Due to Coriolis forces, the northern flanks show condensed sedimentation and slightly increased grain sizes contrasting with the relationships on the opposite flanks.

The age-dating of the cores shows that the modern overflow system was re-established since Termination Ia. Associate problems dealt with are the question of maximum water depth of iceberg plough marks, a possibly biologic origin of huge blocks apparently related to water mass boundaries, and the composition of contourites as manifested in the bedforms.

PRELIMINARY MASS-AGE DISTRIBUTION OF SEDIMENT DRIFTS NORTH OF THE CHARLIE-GIBBS FRACTURE ZONE

C.N. Wold (GEOMAR, Kiel, Germany), W.W. Hay, W.-C. Dullo, T. Wolf, and P. Bruns

We have compiled the masses of sediment in the major sediment drifts that lie between the Charlie-Gibbs Fracture Zone and Greenland-Scotland Ridge. The region was divided into a 1 x 1° latitude-longitude grid, and an average stratigraphic-lithologic section was compiled for each grid cell. The stratigraphy and lithology of each grid cell was derived from reports of the Deep Sea Drilling Project (DSDP) and Ocean Drilling Project (ODP), from single-channel seismic profiles distributed by the U. S. National Marine Geophysical Data Center (Boulder, Colorado), and from literature sources.

To calculate sediment mass-age distributions, several calculations were made for each grid cell. The bulk density of a sediment layer in a grid cell was calculated by multiplying the grain density times the depth-dependant solidity of the layer. The average solidity (100% - porosity) of each sediment layer was integrated over the thickness of the layer using empirical equations for the porosity vs. depth relationships of different sediment lithologies.

ABSTRACTS

NATO Advanced Research Workshop

Carbon Cycling in the Glacial Ocean:
Constraints on the Ocean's Role in Global Change

in alphabetical order of
first authors' names

LATE QUATERNARY PALEOPRODUCTIVITY VARIATIONS IN THE NE AND EQUATORIAL ATLANTIC: DIATOM AND C_{ORG} EVIDENCE

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We have generated 350 ka records of diatom accumulation rates (DAR) and organic carbon derived Export Production (Pexp.) for core 16772 in the eastern Equatorial Atlantic. These records were then compared to previously obtained records for the coastal upwelling areas off Portugal and NW Africa, in order to determine whether common periods of increased productivity have occurred throughout the NE Atlantic.

We find that all the siliceous microfossils accumulation rates correlate very well in each location. By comparing the DAR with the Pexp. we have also found a good coherence between the two records in all locations. This implies that they are both primarily a measure of the same process, the primary productivity at the surface. The eastern Equatorial Atlantic records exhibit a sawtooth pattern, with maxima occurring during Glacial Stages. This sawtooth character is interpreted as deriving from variations in the rate of upwelling through time, and shows that increased primary production has characterized every major glacial period for the last 350 ka in the area. A more detailed comparison of the Pexp. and DAR records reveals that: Both records agree in shape and magnitude with the peaks from 350 to 50 ka. Above the 50 ka the two records diverge and the Stage 2 peak,although present in both records and being of the same order of magnitude as the other glacial peaks in the Pexp. record, has much lower values in the DAR record; The DAR record indicates an increase of both mean and maximum values, by about an order of magnitude, from Stage 8 to early Stage 3, not observed in the Pexp. curve.

Comparison of this oceanic upwelling record with the record of the coastal upwelling areas (KS11 off Portugal and 12392-1 off NW Africa) for the last 120 ka, shows a very similar trend and maxima of the same order of magnitude in both regimes. Times of maximum values for the DAR are however not the same. On the eastern Equatorial Atlantic the most intense DAR peak is observed during Stage 4 but almost not recorded in the coastal upwelling records where the most productive period is Stage 2, and has values 4 times higher than that observed for the same time interval in the oceanic record. The fact that the difference in time of maximum DAR production (siliceous) between oceanic and coastal regimes is not observed for the Pexp. record ($C_{org.}$) may be indicative that a plankton community different from that observed in other glacial Stages has dominated the Equatorial waters during this time.

ISOTOPE STAGE TWO - THE MOST EXTREME GLACIAL TIME WITHIN THE LAST 370,000 YEARS AND THE FOLLOWING "DEGLACIATION" - A RECORD FROM THE CENTRAL RED SEA

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In the Red Sea, the Isotope stage 2 exibits the most severe paleoenvironmental changes during the last 370,000 years. First, there is an obvious trend from stage 10 through 6, and 4 towards heavier $\delta^{18}O$ -values; secondly, the planktic foraminifera survive these glacial maxima, but not stage 2 which indicates drastic changes in the water chemistry. The only survivers belong to the pelagic gastropods, the pteropods: *Creseis acicula.* As demonstrated in the previous poster, the isotope signal of *G. ruber* has to be read as a salinity signal, inferring a salinity maximum at stage 2 coinciding with the maximum sea-level drop and the most severe arid conditions in east Africa. The deglaciation ends around 12,700 y BP indicated by the return of a normal planktic foraminiferal fauna. The following "Younger Dryas" is characterized by a dominance of *G. ruber* and increasing heavier $\delta^{18}O$ values. A similar record can be shown at the isotope-stage boundary 6/5.

THE USE OF NITROGEN ISOTOPIC RATIO FOR RECONSTRUCTION OF PAST CHANGES IN THE MARINE NITROGEN CYCLE AND ITS INFLUENCE ON PALEOPRODUCTIVITY

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At present, there are large regions of the ocean that have perennially high-surface nutrient concentrations. Box model studies have shown that increased biological utilization could have produced the glacial lowering of atmospheric pCO_2, making nutrient uptake an important process to monitor in sedimentary records. Nitrate utilization by phytoplankton in near-surface waters of the ocean is associated with large shifts in the $\delta^{15}N$ of the particulate nitrogen (PN) produced. In the temperate N. Atlantic, $\delta^{15}N$ values increased from -4 to 9 per mil as NO_3^- was depleted during the spring bloom. In the Equatorial Pacific and Southern Ocean, strong latitudinal gradients in surface $\delta^{15}N$ (range ~10per mil) mirror the well-known latitudinal gradients in surface (NO_3) found in these regions. Analysis of large, fast-sinking particles exiting surface waters and in the deep oceans show that these surface-generated signals are transmitted to the sediments. Preservation in the sediments is further demonstrated in data from core-top studies. In the Equatorial Pacific and Southern Ocean, latitudinal variations in sedimentary $\delta^{15}N$ parallel those in surface waters. Moreover, secondary features in surface properties such as the asymmetrical distribution of surface (NO_3^-) about the equator is reflected in the distribution of sedimentary $\delta^{15}N$, giving further confidence in its use as a recorder for past nutrient utilization.
It is apparent, though, that there can be diagenetic increase in sedimentary $\delta^{15}N$. In the Southern Ocean, for example, sedimentary $\delta^{15}N$ values are elevated by about 5 per mil relative to values expected for sinking PN. It is suspected that processes occurring at the sediment/water interface are responsible, perhaps by preferential preservations of organic matter bound in microfossils. More study is required to understand the nature of this diagenetic effect and possible solutions are suggested. Nevertheless, diagenesis appears to act sufficiently uniformly to permit use of relative variations in $\delta^{15}N$ for initial studies of past changes in NO_3^- utilization. For example, Subantarcic waters appear to have had a higher degree of nutrient utilization during the last glacial maximum, but our data do not support massive nutrient depletion for the glacial Southern Ocean.

GLACIAL VERSUS INTERGLACIAL CARBON CYCLING IN THE DEEP OCEAN: THE FORAMINIFERAL RESPONSE

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In modern deep-sea environments foraminiferal standing crop is linked to flux rates of organic carbon. Within the range of flux rates to the bottom from 0.5 g org.

C $m^{-2}yr^{-1}$ (central Arctic Ocean) to 5 g org. C $m^{-2}yr^{-1}$ (subtropical upwelling areas), thresholds are pronounced at 1 g org. C $m^{-2}yr^{-1}$ and 2.5 g org. C $m^{-2}yr^{-1}$. The three assemblages delineated by these threshold levels are dominated most notably by some combination (depending on the area) of species of the genera a) *Uvigerina, Globobulimina, Melonis,* b) *Cibicidoides, Epistominella, Cribrostomoides,* c) *Oridorsalis, Eponides,* and *Nuttalides.* When crossing these threshold levels in space or time, the structure of the biocoenoses changes from being dominated by endobenthic species within sediments enriched in organic matter towards having more filtrating species adapted to food sources in suspension, and species not specialized in any particular feeding behavior or habitat.

In glacial and interglacial environments, main distributional patterns will be affected by climatically induced changes in productivity and flux rates of organic matter when these threshold levels are crossed. Faunal trends in time are found in the fossil record comparable to recent patterns derived from crossing the threshold levels at 1.0 or 2.5 g org. $m^{-2}yr^{-1}$ in space. Unfortunately, things grow more complicated when we try to separate vertical flux rates and lateral advection of organic matter. For suspension filtrating foraminifera, threshold levels depend less on the organic carbon content of the sediments than on the organic carbon carried by currents and lateral transport.

To consider the meaning and stability of $\delta^{13}C$ measures from benthic foraminiferal tests, habitat preferences of numerous species were scrutinized in sediment columns. However, observations on the trophic behavior of species raise more questions than can be answered by static depth profiles: Why may endobenthic species aggregate directly below the sediment surface? Why are suspension feeders found even below the sediment surface? Why is the rate of enzyme activity in some benthic foraminifera higher than for any other benthic metazoan? Pacemaker for most of the answers needed is neontological research on the trophic behavior of one of the most important consumers in deep-sea environments: benthic foraminifera.

ATMOSPHERIC RADIOCARBON DURING THE LAST DEGLACIATION: CONSTRAINTS FOR MODELING THE CARBON CYCLE

Edouard Bard (Géosciences de l'Environnement, Marseille, France)

The atmospheric $\Delta^{14}C$ record of the last deglaciation has been the subject of numerous investigations in the past few years by means of dendrochronology, varved sediment chronology and radiochronology.

Several studies have revealed the presence of so-called ^{14}C age plateaus superimposed on the long term variation of the $\Delta^{14}C$ since the Last Glacial Maximum.

Moreover, the ^{14}C age plateaus did not occur randomly but correspond to abrupt climatic transitions such as the end of the Younger Dryas event ($\approx$10,000 and $\approx$9600 conventional ^{14}C yr BP) and the beginning of the Bølling-Allerød period ($\approx$12,600 conventional ^{14}C yr BP).

The age plateaus lasted typically 300 to 500 calendar years and correspond to rapid falls of the atmospheric $\Delta^{14}C$ which cancelled the ^{14}C decay.
Two causes can be proposed to explain both aspects of the age plateaus: variations of fluxes between reservoirs of the global carbon cycle and fluctuations of the ^{14}C production rate due to solar activity. I will present simulations of these two effects which were obtained by means of a 13-box numerical model including ocean, soil, biosphere and atmosphere.

VOSTOK ICE CORE; UPDATING OF CO_2 DATA AND PHASE RELATIONSHIP BETWEEN THE DIFFERENT PARAMETERS DURING THE CLIMATIC TRANSITIONS

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CO_2 measurements performed on the upper 2,050 m of the Vostok ice core have already provided a record of the atmospheric CO_2 variations back to the marine stage 6. We present here new data from the deepest part of the core, that is down to 2,543 m. Based on the comparison of the Deuterium profile with marine records (in particular the S.S.T. of RC 11-120), the marine stage 7 could be attained. CO_2 results obtained below 2,500 m indicate concentrations around 245 ppmv, value lower than the 280 ppmv found during the full interglacial periods (stage 1 and 5c), but hgiher than the values around 230 ppmv found during the first part of the last glaciation (stage 5a to 5d).

We will also discuss the phase relationship between the different gaseous components (CO_2, CH_4 and atm ^{18}O), the Vostok temperature and then the sea-level variations during the climatic transitions. A special emphasis will be made on the importance of the hypothesis made on the past accumulation rates.

PALEOPRODUCTIVITY: SOME OPEN PROBLEMS

W.H. Berger (Scripps Institution of Oceanography, La Jolla, USA)

The paleoproductivity signal at any one place on the seafloor carries information concerning both the changes in overlying waters and changes in the global conditions of ocean production. As far as the pelagic record, the two factors are likely to have opposite signs. Increased global productivity will sequester certain means of production (phosphate, silica) into the margins, impoverishing the open ocean thermocline in the process. There is evidence that this process was active in the Neogene.

Was the Neogene ocean more productive than the Paleogene one? How would we know? If yes, what were the underlying factors responsible? It is evident that such very basic questions are difficult to answer. The study of large-scale facies segregation is offered as one means to assess global changes in overall productivity.

CD AND $\delta^{13}C$ DATA FROM THE MODERN AND GLACIAL MAXIMUM OCEAN: CAN THEY BE RECONCILED?

E.A. Boyle (MIT, Cambridge MA , USA)

It has been useful for paleoceanographers to use Cd and $\delta^{13}C$ in fossil foraminifera to look at past nutrient distributions and their implications for ocean circulation patterns and atmospheric carbon dioxide. As more data has become available, it is clear that fossil evidence for the nature of glacial ocean nutrient distributions provided by Cd and $\delta^{13}C$ is not compatible if we insist on using a simple nutrient analogy for both tracers. For example, glacial maximum $\delta^{13}C$ data surprisingly suggests that Antarctic Ocean deep water had higher nutrients than anywhere else in the ocean, while Cd data suggests that the Eastern Tropical Pacific deep water was the highest in nutrients (just as it is today). Similarly, $\delta^{13}C$ data indicates that the nutrient content of glacial maximum Antarctic surface waters was higher at present; Cd indicates that it was about the same as at present. These and other examples will be presented to set the stage for the obvious question: is one or both tracers misleading us, or are we are incorrect in ascribing simple nutrient-like behavior to one or both of these tracer during glacial times?

At first order, Cd and $\delta^{13}C$ both follow global ocean nutrient (e.g., P) distributions because they are taken up into and transported vertically by the soft-tissue particle cycle. At closer look, both tracers depart significantly from strict nutrient-like behavior: $\delta^{13}C$ is influenced by gas exchange and Antarctic plankton are more highly depleted in ^{13}C than low-latitude plankton, and Cd is not always taken up by plankton relative to P in the same ratio as occurs in the water they grow in. This presentation will examine the differences between Cd, $\delta^{13}C$, and P in the modern ocean and global weathering cycle and explore whether these differences are sufficient to account for the glacial maximum discrepancies between these two tracers.

The conclusions to be drawn from this work are:

(1) Both oceanic Cd and $\delta^{13}C$ are sufficiently different from P behavior to foreclose their use as a strict nutrient analogs, but these differences are not so great that they prevent the use of these tracers to derive paleo-nutrient distributions within the context of an ocean chemical model.

(2) Differences between Cd, $\delta^{13}C$, and P are largely irrelevant to their use as deepwater circulation tracers. Any nonconservative tracer is useful to the extent that it's boundary conditions are known and internal nonconservative behavior can be delimited. These tracers are equally good (and equally bad) deep-water ocean circulation tracers.

(3) The Cd-$\delta^{13}C$ differences that we understand to-date do not appear to account for the magnitude of the differences between the glacial maximum data.

BENTHIC CARBONATE PRODUCTION DURING GLOBAL CHANGE : THE CARBONATE RECORD OFF THE BALEARIC ISLANDS

M. Canals (Universitat de Barçelona, Barçelona, Spain)

The role of the ocean in regulating CO_2 concentrations in the atmosphere should be influenced by the sustained capacity of the benthic communities to produce not only biomass but also carbonate particles which are detracted from the carbon cycle to form sediments and built continental margins.

Mid-latitude shelf carbonates have merited increasing attention in recent literature, i.e., the 1988 Special Issue of "Sedimentary Geology". However, as Bice (1991) points out, there is still relatively little information from modern carbonate environments that documents how the sediment production rate varies with water depth. As a consequence, modelers are forced to make assumptions when running their models that very often have not been satisfyingly proven.

Our communication aims to provide additional data on the Balearic Islands continental shelf benthic communities producing carbonate particles, and also on the cumulative results, i.e., the sediment record, of such activity as revealed by high-resolution seismic reflection profiles from the insular margin.

Carbonate-producing benthic communities are sensitive to a wide range of environmental changes having different frequencies, from a geological time scale (hundreds of thousands of years to millions of years) to a seasonal (some months) and even a diurnal one. All the resulting responses are overimposed in the same way that waves of varying frequencies and amplitudes could be.

Benthic contribution to carbonate particle production depends, first of all, on the surface available for benthic communities to grow. Continental shelves emersion and submersion cycles are dependent on geotectonic and climatic-eustatic cycles, the surface available for benthic communities is. Thus, due to morphological constrains, i.e. shelfbreak depth and seaward rise of vertical gradients, the surface is reduced to its minimal expression during lowstand periods, while the contrary occurs in highstand periods. Then, benthic carbonate particle production should be much greater in highstands than in lowstands. Since extensive progradation over the outer shelf and upper slope is evident in the Balearic margin, effective exportation processes should exist. High resolution seismic reflection profiles also show that these processes create oversteepenings at the shelfbreak and subsequent instability events responsible for sudden massive exportation events contributing to margin building.

Another crucial point to correctly assess benthic community responses to external changes is to know how production rates vary with slight changes of seawater and atmosphere physical parameters, like temperature, irradiancy and others, plus ecobiochemical changes, like trophic structure or nutrient availability variations, that certainly occurred in the last glacial period. Precise identification of existing benthic communities taking the carbonate production rate as one of the diagnostic parameters is then necessary, as it has been done in selected areas of the Balearic shelf. Because of the significant variations in production rates from community to community, to establish the depth ranges and areas occupied by each community becomes critical to obtain at least the present total carbonate budget. Moreover, as stated by Ballesteros (1984), nowadays the carbonate production rate for one single community, i.e. photophyllic algae, can vary from one place to another by a factor of two to six depending on environmental stresses and maturity of the community. If this is occurring now, what may not have occurred along an entire glacial cycle ?

DINOFLAGELLATE CYSTS AS PALEOENVIRONMENTAL AND PALEOPRODUCTIVITY INDICATORS: STATE OF THE ART, POTENTIAL, AND LIMITS

B. Dale (Dept. of Geology, Oslo, Norway)

Dinoflagellate cysts are a group of microfossils, best known for their widespread use in biostratigraphy of oil exploration. However, research on the distribution of living cysts increasingly is showing strong ecological "signals", suggesting a potential for using cysts more also as paleoenvironmental indicators.

Around 250 Quarternary and recent cyst species are known. Most are acid-resistant (palynomorphs), presumably due to the presence of sporopollenin-like material in the cyst wall, though some calcareous forms are known. The acid-resistant cysts are useful, not least, in sediments where mineralized microfossils such as forams, diatoms, and calcareous nannofossils are absent (e.g., due to dissolution).

By far the most cysts are produced in coastal to outer neritic waters, where they are sensitive water mass indicators (e.g., reflecting: 1. temperature-controlled biogeographic zones comparable to the standard zones established for molluscs, fish, macroalgae, etc., 2. both high and low salinity environments, and 3. upwelling). Recent work by Dale and Madsen shows that cysts are potentially good indicators of paleoproductivity: dramatic changes in cyst assemblage accompanied the massive eutrophication of a Norwegian fjord during the past 150 years (quantitatively, from < 10,000 to > 150,000 cysts/g sed., and qualitatively, with a complete shift in species dominance).

Until fairly recently, the only information from the deep sea was obtained from a variety of bottom-sediment samples, collected by dredges or corers. Comparisons between deep-sea distributions, modelled from such samples, and the coastal distributions of the same cyst species show marked decrepancies (e.g., species restricted to the cold temperate zone in coastal waters, but ranging into the tropical zone in the deep sea). More recent work with deep-sea sediment traps has helped to better define and quantify which cysts are actually produced in pelagic waters thereby representing the "*in situ*" deep sea signal. These studies suggest that many of the cysts in deep-sea sediments may be transported long distances, from nearer shore environments. Even in abyssal sediments, cyst assemblages may be dominated by transported, "coastal" cysts, since relatively few pelagic cysts are produced. This will have to be taken into account when interpreting paleoceanography from deep-sea sediments, and the application of traditional transfer functions to cyst assemblages.

DIAGENETICS, AND HOW IT MAY EFFECT VARIOUS PALEO PROXIES

G.J. de Lange (Institute of Earth Sciences, Utrecht, The Netherlands), B. van Os, and P.A. Pruysers

The search for paleo tracers has been much intensified in the last decade, resulting in a number of potentially useful tracers for paleo temperature/paleo salinity, paleo productivity, etc.. Meanwhile, it has become evident that a number of limitations exist on the inconsiderate application of these tracers. It is now known, that early diagenetic processes may considerably alter the primary signal. Consequently, one must be very cautious when applying a paleo-tracer that is sensitive to diagenetic alterations. Some of these alterations will be discussed here.

One of the first parameters used to estimate the paleo-ocean productivity was the organic carbon contents of the sediment. However, the organic carbon content is not only dependent on the ocean productivity, but also on the sedimentation rate, and the origin and diagenetic history of the organic matter. Origin and diagenetic history may vary for different environments, and may show preferential preservation for some groups of compounds. As a consequence the organic carbon contents, and its $\delta^{13}C$ and $\delta^{15}N$ may be altered dramatically during early diagenetic processes. It is remarkable in this respect, that the organogeochemical molecular biomarker for paleotemperature ($U_K{}^{37}$) seems unaffected by the post-depositional decomposition of organic matter The occurrence of Mn spikes over large areas of the tropical Pacific has been used to establish the history of oceanic/atmospheric chemistry (Berger et al., 1983). Although the formation of the Mn spike itself was stated to be diagenetic, its origin was attributed to the activity of benthic burrowing organisms, which, in turn, is dependent on the ocean productivity. The formation of such a \`paleo´ Mn spike can also be explained by early diagenetic mobilization alone In both cases a clear change in the benthic flux of organic carbon is necessary. If true, the occurrence of a Mn spike would be a potential proxy for (changes in) ocean productivity. These very spikes may only be preserved under certain diagenetic conditions (e.g., Finney et al., 1989). A Mn spike may also originate from a short event of hydrothermal emanations. However, this is likely to be a local phenomenon only. Barite is a common mineral in marine sediments. Its distribution and relative concentration levels in the sediment seem related to biogeochemical fluxes/cycles. Ba has, therefore, been suggested as a possible paleoproductivity proxy. However, some studies have shown that great care must be taken in using Ba as a paleoproductivity indicator, as it is subject to diagenentic mobilization in an anoxic environment. A similar enrichment process has been proposed to explain the Ba enrichment for Cretaceous black shales, although this hypothesis has more recently been questioned. Variations in the rain rate of Ba may not only be controlled by the ocean productivity, but may also arise from salinity excursions or hydrothermal emanations. These variations are likely to be of local importance only. Pseudo paleomagnetic Reversals: The formation of magnetite (Fe_3O_4) during early diagenetic processes in a suboxic (possibly reducing) environment is known to change the magnetic susceptibility. Potentially, such formation may induce pseudo-paleomagnetic reversals to occur near a real reversal event. This occurrence has recently been observed for some Pliocene sediments The bulk carbonate content, and the relative concentration of some microfossils may be affected by early diagenetic processes. Decomposition of organic carbon leads to dissolution of carbonates, whereas the oxidation of upward-moving methane may lead to the precipitation of carbonate with a dramatically different isotope (and possibly trace element) signature. The selective dissolution of carbonate may change the relative distribution of microfossils.

CARBON ISOTOPES IN PLANKTONIC FORAMINIFERA AS A MEASURE FOR PALEOPRODUCTIVITY IN THE UPWELLING REGIONS OFF OMAN, NW- AND SW-AFRICA

G. Ganssen (Institute of Earth Sciences, Amsterdam, The Netherlands), R. Schneider, and R. Zahn

The modern high-productive upwelling regions in the Indian Ocean clearly leave an imprint on the carbon isotopes of planktonic foraminifera. While *Globigerina bulloides* is enriched in the heavy isotope carbon 13, *Neogloboquadrina dutertrei* gets is depleted. As a result, the difference in the carbon isotope composition between these two species is a measure for productivity, with low values indicating high productivity.

Application of this tool on sediments from ODP site 728A off Oman results in the upwelling history of this region for the past 500 ka.

Off Northwest Africa, the carbon isotopic difference between *G. bulloides* and *Globorotalia inflata* from surface sediments reflects the southern high-productive area by a relatively small difference in the carbon isotope compositions. The northern, relatively low productive region is characterized by a relatively large difference. Data from different piston cores enable us to reconstruct the productivity history from the NW-African continental margin for the past 30 ka. A 135 ka record is obtained for piston-core 12392-1 and compared with other paleoproductivity proxies.

Off Southwest Africa, the carbon isotope differences in the cores GeoB 1008-3 and 1023-5 based on *G. bulloides, Globigerinoides ruber* and *G. inflata*, respectively, corroborate the two to three times higher production rates during the glacial intervals for the past 200 and 30 ka, respectively, as derived by the "Mueller & Suess" method.

FORAMINIFERAL POPULATION DYNAMICS, STABLE ISOTOPES AND PALEO-ENVIRONMENT IN THE RED SEA AND ATLANTIC

C. Hemleben (Institut und Museum für Geologie und Paläontologie, Tübingen, Germany) and J. Bijma.

The reproductive cycle of planktic foraminifera depends, in general, on the lunar phase. This implies that the size distribution in the photic zone is biased by the lunar day. In addition, most planktic foraminifera, if not all, change their life horizon during ontogeny. Thus, the isotopic composition of the foraminiferal shells is controlled by the total life history. This may be part of the so-called vital effect. In addition, water-mass properties (e.g., oligotrophic vs. eutrophic) influence the isotopic composition of the shells and regulate the faunal compositon. The geographic and climatic setting determine both features (e.g., upwelling, monsoon, etc.). We will show in a few examples that a thorough understanding of the population dynamics of recent planktic foraminifers is important for the interpretation of paleoenvironmental settings. We will focus on *G. sacculifer* and *G. ruber* from the Red Sea and on *G. bulloides* and *O. universa* from the North Atlantic.

THE HAMBURG OCEANIC CARBON CYCLE CIRCULATION MODEL AND THE LAST GLACIATION, MODEL TECHNIQUE, EXPERIMENTS, AND INTERPRETATION

C. Heinze (Institut für Meereskunde, Hamburg, Germany).

The Hamburg Carbon Cycle model (developed at the Max-Planck-Institut at Hamburg by E. Maier-Reimer with contributions of R. Bacastow) covers the entire world ocean with a 3-dimensional grid (72x72x11 points in EW, NS, and the vertical direction). Carbon cycle relevant tracers are advected by a velocity field provided by the Hamburg Large Scale Geostrophic model in a separate dynamical computation. The major carbon cycle relevant geochemical processes so far identified by observations are included. In the annually averaged version, the model allows integration periods up to ten thousands of years. Prognostic variables of the model are three-dimensional tracer distributions (dissolved inorganic carbon, particulate organic carbon, particulate calcium carbonate, alkalinity, PO_4, oxygen) and two-dimensional distributions of the tropospheric CO_2 airborne fraction and oceanic sediment pools $CaCO_3$, organic carbon). The three carbon isotopes ^{12}C, ^{13}C, and ^{14}C are considered throughout.

Two different groups of sensitivity experiments relative to the pre-industrial holocene ocean as reference have so far been carried out that are of significance with respect to the glacial ocean: experiments with changes in biogeochemical parameters and experiments with changes in the oceanic circulation. Though a considerable reduction of the modelled atmospheric pCO_2 and some similarity of the resulting tracer distributions with reconstructions of the situation during the last glaciation could be achieved. Model results and observations presently show discrepancies.

Interpretation of model results and comparison with observed data is limited by the model's resolution (space, time, processes), the transient behavior of the real ocean itself, quality and coverage of the observational data base.

RECONSTRUCTION OF HIGH-LATITUDE FRONTS AND CONVECTIVE REGIONS: COMBINED STABLE ISOTOPE, FORAMINIFER, AND SEDIMENT APPROACH

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Reconstructing the thermohaline circulation is an important element in understanding glacial-interglacial variations in the carbon cycle. We present a multi-parameter approach to the problem of identifying the position of the Polar and Arctic Fronts and the definition of potential convective regions, based on a comprehensive set of box core tops covering the main oceanographic fronts and convection regions of the GIN-seas. Mapping of foraminiferal faunal distribution, foraminiferal flux, stable isotopes and IRD provides unique combinations of data which define the present surface water masses, fronts and the convective regime in Arctic waters with good precision. These combinations can then be applied to past conditions. The Polar Front is defined by lowered foraminiferal flux, a small maximum in the relative abundance of *G. quinqueloba*, lowered $\delta^{18}O$, lowered $\delta^{13}C$, and significant IRD content. The Arctic Front is defined by high foraminiferal flux, >90% *N. pachyderma* sin., enhanced $\delta^{18}O$ and $\delta^{13}C$, and variable IRD content. The Norwegian Coastal Front is defined by lower foraminiferal flux and more negative $\delta^{18}O$ in *G. quinqueloba.* Present deep-water formation takes place in Arctic waters which are a mixture of Polar and Atlantic surface waters. This Arctic water regime is uniquely described. The high foraminiferal flux, and high $\delta^{13}C$ reflects long sea-ice-free seasons with good gas exchange, and the enhanced $\delta^{18}O$ and monospecific fauna, reflects the low SST. Polar waters which are characterized by semi-permanent ice cover are described by reduced foraminiferal flux and $\delta^{13}C$, reflecting lower productivity and lowered gas exchange, and the lower $\delta^{18}O$ reflects the low salinity of these waters. Using these criteria on maps reconstructed for the Last Glacial Maximum and the last deglaciation ,we provide evidence for convective regions in the GIN-seas/North Atlantic and the paleo-position of fronts.

CARBON ISOTOPIC RECONSTRUCTIONS OF OCEANIC AND EQUILIBRIUM ATMOSPHERIC CO_2 LEVELS FROM SEDIMENTARY BIOGENIC COMPONENTS

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Three case histories of compound-specific isotopic reconstructions of dissolved and equilibrium atmospheric CO_2 levels will be presented in the context of the underlying principles of a recently developed method. The carbon-isotopic fractionation accompanying photosynthetic fixation of CO_2 (ε_p) depends on the concentration of dissolved CO_2 and is recorded in marine sediments by phytoplanktonic biomarker compounds and coeval carbonates (Popp *et al.*, 1989). Case histories from the late Qua-ternary (the northern Gulf of Mexico, the central equatorial Pacific, and the Black Sea) exemplify near equilibrium, non-equilibrium, and exotic pCO_2 environments. In 1990, Jasper and Hayes calibrated an ~100 ka eP record from the Pigmy Basin (DSDP 619) in the northern Gulf of Mexico against equilibrium CO_2 (aq) concentrations calculated from the Vostok ice core pCO_2 values (Barnola *et al*, 1987). In that case, the ε_p record was derived from the sedimentary remains of Prymnesiophyte microalgae (a C_{37} alkadienone, heptatriconta-15,22-dien-2-one) and the carbonate tests of a planktonic foraminifera (*Globigerinoides ruber*). The carbon isotopic composition ($\delta^{13}C$) of the C_{37} alkadienones was determined by isotope ratio monitoring gas chromato-graphy/mass spectrometry techniques (Freeman *et al.*, 1989). Given the calibration and independent estimates of ε_p-[CO_2] relationships, time-series records of [CO_2 (aq)] for Pigmy Basin surface waters and of equilibrium atmospheric pCO_2 were generated. Recent paleoceanic pCO_2 results from a central equatorial Pacific (MANOP Site C) sediment core correspond well with a global climatic $\delta^{18}O$ record from isotope stages 7 through mid-5, but markedly and explicably diverge thereafter. The range of pCO_2 values at MANOP Site C is attenuated (200-250 matm) relative to the pCO_2 record of the Vostok ice core (190-280 matm), plausibly caused by tradewind-induced upwelling, photosynthetic CO_2 drawdown, and glacial-to-interglacial variations in oceanic P/dissolved CO_2 ratios. A study on Black Sea sediments illustrates biosynthetic and environmental effects on the $\delta^{13}C$ of individual biomarker compounds. Recent $\delta^{13}C$ results from a high-resolution box core (^{210}Pb-dated by Crusius and Anderson, 1992) from the western Black Sea show that $C_{37:3}$-alkenones were 1.0±0.5‰ depleted in ^{13}C relative to $C_{37:2}$. Concordant with the principle of the U^K_{37} paleothermometer (Bras-sell *et al.*, 1986), the more highly unsaturated compounds ($C_{37:3}$) were apparently synthesized in colder (and typically deeper) and CO_2-enriched waters in which greater isotopic fractionation will have occurred. In addition, the $\delta^{13}C$ of a coccolith-carbonate-enriched sediment fraction decreased from 2.63‰ to 2.14‰ over the last 145 a. This ~0.5‰ ^{13}C-depletion corresponds well with the decrease observed in Bermuda corals (Nozaki *et al.*, 1978) and in paleoatmospheric CO_2 entrapped in recent ice cores (Friedli *et al.*, 1986). The correspondence between these $\delta^{13}C$ records indicates that the surface waters of the Black Sea, although a source of CO_2 to the contemporary atmosphere (Goyet *et al.*, 1991), isotopically exchange with the atmosphere on relatively short (decadal) time scales. The potential and limitations of the ε_p-based pCO_2 reconstructions will be discussed.

RESPONSE OF AGGLUTINATED BENTHIC FORAMINIFERA TO DYSOXIC CONDITIONS IN THE CALIFORNIA BORDERLAND BASINS

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Analysis of agglutinated benthic foraminifera from surface samples collected in the San Pedro and Santa Catalina Basins reveals a predictable relationship between the proportions of morphogroups with decreasing bottom-water oxygen levels, and with the TOC content of the surficial sediment.

Living foraminiferal faunas from dysoxic environments display low diversity and high dominance, suggesting stressed conditions. There is an inverse relationship between oxygen and the relative abundance of deep infaunal morphogroups.

Samples collected from shallow stations, above the oxygen minimum zone, are comprised of epifaunal and shallow infaunal morphotypes. At intermediate depths (~500 m), there is a peak in the abundance of suspension-feeding and "climbing" forms. Specimens from intermediate stations display the largest overall size. Deeper in the San Pedro Basin the living fauna is dominated by a small, flattened, tapered, species that is interpreted as having a deep infaunal microhabitat. In the dysoxic environments off California the greatest degeree of faunal change occurs when bottom-water dissolved oxygen values drop from 0.5 ml/l to 0.2 ml/l.

Agglutinated faunas from areas that experience seasonal anoxia are comprised of opportunistic forms, such as *Reophax* and *Psammosphaera*. These are the same taxa that colonized abiotic sediment trays in a recolonization experiment in the Panama Basin.

The effect of TOC content on the benthic fauna is demonstrated at two stations from the same depth in the San Pedro Basin. The station with the higher TOC content (4.2% vs. 2.9%) contains greater proportions of the small, deep infaunal morphotype. These faunal changes may be attributed to differences in t he depth of the oxygenated zone within the sediment surface layer.

CARBON AND OXYGEN ISOTOPE ANALYSES OF CARBONATES IN PLEISTOCENE CONTINENTAL DEPOSITS: A PALEO-ENVIRONMENTAL TOOL IN GLOBAL CHANGE STUDIES?

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Three case studies on the stable isotopic composition of carbonates in Pleistocene continental deposits are presented. The major goal of these studies is to test (1) the reproducibility of the δC and δO signals within lithostratigraphic units, and (2) their variation between different units.

In a first study (on the Lishi formation of the Luochuan loess section, China) a total of about 1,200 analyses were carried out on pedogenic carbonate concretions from 18 different horizons in paleosoils, as well as on carbonate from the loess matrix inbetween.

In a second study on geosoil sequences in the Barind area, Bangladesh, about 300 samples were analyzed (more than 500 analyses) from 5 different lithostratigraphic units. Here all samples come form (different types of) concretions, many of them containing up to 5 different concentric "growth" layers.

In a third study, 230 samples were analyzed from two correlated loess paleosoil profiles in Riedel and Kaiserstuhl, Germany. Only matrix carbonate material was analyzed (every 20 cm) throughout the whole section.

In a very simplified expression, the observations can be summarized: Carbon and oxygen isotope signals vary significantly more between different lithostratigraphic units than within them.

study area	(1) China	(2) Bangladesh	(3) Germany
range in δC	-8‰ to -2.5‰	-11.5‰ to +1.5‰	-8.5‰ to -1‰
range in δO	-10‰ to -8‰	-6‰ to -3.5‰	-7.5‰ to -4‰

Table 1

The larger variations found in the carbon isotopic compositions (Table 1) may be explained by climatically induced changes in floral composition. Changes in humidity are translated in variations of C3- and C4- plant proportions, resulting in changing soil CO_2 δC values,. the extreme δC values found, would correspond to nearly single "phase" C3
(δC: -11.5‰) or C4 (δC: +1.5‰) floras.

The smaller differences observed in the oxygen isotopic compositons (Table 1) can be induced by temperature changes. Contrary to the mechanisms in the marine environment, here the "direct" temperature-effect, causing the change of the fractionation factor between (soil-) water and (soil-) carbonate, is opposite to the "indirect" temperature-effect, controlling the isotopic composition of the (meteoric and thus soil-) water.

PALEOHYDROGRAPHY OF THE LAST GLACIAL OCEAN: THE CURRENT STATE OF WISDOM

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Knowledge on the general hydrography of the glacial ocean has increased significantly over the last few years. For surface water, the early sea-surface temperature reconstructions of CLIMAP and others, based on micropaleontology, have been completed with similar methods. Sea-surface salinity maps are developed, using the reconstructed SST values to correct from isotopic fractionation the measured planktic foraminifera $\delta^{18}O$, and the modern relationship between water salinity and $\delta^{18}O$. The North Atlantic map for 18 ka BP has been published (Duplessy et al., 1991), and other maps will be presented for the Equatorial and the Southern oceans. Constraints on the vertical distribution of temperature and salinity (thus density) may be derived from the benthic foraminifera $\delta^{18}O$ and the surface-water data. Briefly, in the North Atlantic Ocean the whole water column was cooler by 2 to 5°C, and the density distribution was more homogeneous than in the modern ocean for intermediate and deep waters.

Additional data on the distribution of benthic foraminifera $\delta^{13}C$ help to make the general picture more precise. The Northern Atlantic Ocean may have been an active source of deep (poorly ventilated) and intermediate (ventilated) waters during most of the last glacial period.

Another approach is being developed for these reconstructions, which is based on high-resolution isotopic studies (each 1 to 3 cm) of planktic and benthic foraminifera in high sedimentation rate cores. A succession of large meltwater events (of low $\delta^{18}O$) is clearly visible in both types of records, and may be used to track the general circulation.

THE RECENT STATE OF CARBON CYCLING THROUGH THE ATMOSPHERE

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Any attempt in understanding the recent atmospheric carbon cycle has to imply its large perturbations by man's impact: the long-term emissions of carbon dioxide and methane associated with fossil-fuel burning on one hand, and land-use changes, as a consequence of an exponentially increasing human population on earth, on the other hand, which have caused substantial increases of both trace gases in the atmosphere.

In the case of atmospheric carbon dioxide, the yearly anthropogenic emissions are small, however, if compared to the exchange rates between the most important reservoirs - biosphere and ocean. These natural exchange rates, on the global scale, are accessible only via observations in combination with atmospheric and ocean circulation models. Changes of carbon inventory in these reservoirs are, thus, even more difficult to observe, and the question, how much of the anthropogenic excess CO_2 generated today enters the biosphere or the ocean, cannot be answered unambiguously.

In the case of atmospheric methane, anthropogenic emissions today exceed natural release rates by about a factor of two. As for carbon dioxide, the recent global methane budget is mainly derived from observational evidence in the atmosphere. However, although the total yearly methane source today is accepted to be known within ±10 to 20%, the variability in the estimates of individual sources, particularly in natural emissions, is certainly larger. For example, the role of the global ocean as a source (or sink) of atmospheric methane still remains unclear.

A summary of our knowledge about the recent carbon cycle will be presented from the perspective of the atmosphere. In attempting to disentangle the complexity of the recent carbon cycle, emphasis will be given on isotope studies as an experimental tool being used most profitably where the detailed information on the spatial and temporal variability of sources and sinks is missing. The yet unknown parameters influencing the levels of the atmospheric trace gases, carbon dioxide and methane, will be discussed in the perspective of their variations in the past. Actually, there are large uncertainties in the quantitative determination of the coupling constants. Keeping in mind that these constants have changed in the past, the question arises: is there any information left about the ancient carbon cycle?

BENTHIC FORAMINIFERAL ASSEMBLAGES AND THEIR $\delta^{13}C$-SIGNAL IN THE ATLANTIC SECTOR OF THE SOUTHERN OCEAN: GLACIAL-TO-INTERGLACIAL CONTRASTS

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Live benthic foraminiferal assemblages from between the eastern Weddell Sea continental margin and the Walvis Ridge in the eastern South Atlantic have been correlated with bottom water mass characteristics, surface sediments and productivity in the surface water. Via calculation of "potential fossil" assemblages a concept is developed that interrelates benthic faunas with North Atlantic Deep Water (NADW), Circumpolar Deep Water (CDW) and Antarctic Bottom Water (AABW), as well as surface productivity. Towards the highly productive Polar Front region, an increasing number of infaunal species gradually changes the faunal character from low-productivity and specific water mass indicating faunas to high-productivity indicating faunas. The high-productivity endmembers, however, are still assigned to northern deep water and southern component bottom water masses, respectively. We compared the $\delta^{13}C$ of *Cibicidoides* from surface sediment samples with $\delta^{13}C$-values of ΣCO_2 of the directly overlying bottom water. The $\delta^{13}C_{Cib.}$ from north of the Subantarctic Front at ≈45°S is in a 1:1 relationship with bottom water $\delta^{13}C_{\Sigma CO_2}$, whereas south of 45°S, the $\delta^{13}C_{Cib.}$ is by up to 0.4‰ lower than $\delta^{13}C_{\Sigma CO_2}$, of the bottom water.

Glacial-to-interglacial contrasts are documented by two virtually undisturbed *Polarstern* cores, (1) from the lower bathyal Antarctic continental margin at 69°S, and (2) from the abyssal Agulhas Basin at 43°S:

1. Today, the Antarctic continental margin site is bathed by AABW. The interglacial situation with bottom water generation in the Weddell Sea and seasonally open surface water is relected by a high opal accumulation rate, very low carbonate and moderate total organic carbon (TOC) accumulation, a benthic foraminiferal fauna that indicates moderate productivity, as well as the same high $\delta^{13}C_{Cib.}$ and $\delta^{13}C_{planktic}$ values of 1.0‰. During the last glacial maximum, a very low opal accumulation rate, a moderate carbonate accumulation, a benthic fauna that indicates low productivity, $\delta^{13}C_{Cib.}$ values of 0.3‰ and $\delta^{13}C_{planktic}$ values of -0.1‰ are consistent with both a reduced primary productivity and a reduced southern bottom water generation.

2. Today, the Agulhas Basin site is bathed by lower CDW with a strong AABW component. High carbonate, low opal and low TOC accumulation, and a specific southern benthic fauna that indicates low productivity, as well as $\delta^{13}C_{Cib.}$ values of 0.3‰ reflect the late Holocene position north of the Polar frontal zone and the supply

of NADW and its strong admixture to the CDW in intermediate depths. We calculated an interglacial primary productivity of ≈40gC/m²/year. During the last glacial maximum, a particular southern high-productivity benthic fauna, low-carbonate, high opal, sediment and TOC accumulation, and low $\delta^{13}C_{Cib.}$ values of -0.9‰ indicate a bottom water mass of southern origin, a northward shift of the high productivity belt of about 8° latitude, as well as a strongly diminished injection of northern component deep water into the Southern Ocean. The calculated glacial primary productivity was ≈80gC/m²/year.

The data suggests that the $\Delta\delta^{13}C_{interglacial\text{-}glacial}$ contrast in the eastern Atlantic sector of the Southern Ocean is 0.7-0.8‰ if correcting the Agulhas Basin data by 0.4‰ for a northward migration of the high productivity belt. The remainder of ≈0.3‰ to the inferred global amplitude of 0.46‰ is caused by the demise of NADW in the last glacial maximum.

^{230}Th, ^{231}Pa AND MANGANESE: INDICATORS OF CHANGES OF OCEAN CHEMISTRY

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High-resolution studies on deep-sea sediments and on Mn-crusts suggest that Mn in the ocean may be of importance in controlling the concentration of atmospheric CO_2. This cyclic variation of the Mn-concentration could explain some of the very rapid increase of atmospheric CO_2 that has been observed in ice cores at the glacial-interglacial boundaries.

Our hypothesis is based on the idea that the concentration of dissolved Mn^{2+} in the deep sea is sensitive to changes of the organic matter concentration in the water column (Eh). We assume that during glacial periods, when the biologic CO_2-pump was more efficient in transferring atmospheric CO_2 into the ocean, the concentration of dissolved Mn^{2+} increased by orders of magnitude in comparison to the present day (interglacial) concentration. This excess of Mn^{2+} leads to an increase of the alkalinity in the glacial ocean in the range of several micromols and consequently to an enhanced storage of CO_2 in the deep ocean. Returning to interglacial conditions is assumed to go along with a precipitation of MnO_2, which corresponds to a rapid drop of the alkalinity and to a rapid release of CO_2 to the atmosphere.

In sediments cores from localities close to hydrothermal areas (the major marine source of Mn) we observe lower Mn/Fe ratios during glacial periods suggesting a longer glacial residence time of Mn in the water column. Further, peaks of Mn in cores from open ocean localities at glacial/interglacial boundaries reflect precipitation of Mn at periods of climatic amelioration. Radioisotopic measurements on pelagic Mn-crusts performed at extreme high resolution show periods of growth standstill or slower growth during glacials.

The change of the residence time of Mn in the water column could also be of importance in the control of the flux of ^{230}Th into sediments. High resolution studies on deep sea sediments show peaks of ^{230}Th at the glacial boundaries 6/5, which could suggest a change from a longer glacial to a shorter interglacial residence time of ^{230}Th in the water column.

GLACIAL-HOLOCENE PALEOPRODUCTIVITY OFF WESTERN AUSTRALIA: A COMPARISON OF PROXY RECORDS

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The CLIMAP sea-surface temperature (SST) reconstructions for the last glacial maximum (LGM) Indian Ocean show a zone of relatively cool water off the west coast of Australia. These lower SSTs ($\Delta T \geq -4°C$) stand in contrast with the small LGM SST increases calculated for most of the tropical and subtropical Indian Ocean. The CLIMAP studies suggested that this region of lower SST was the result of equator-ward transport of cold water due to the more northerly position of the Glacial West Wind Drift, a portion of which is suggested to have been diverted to the north after impinging on Australia; at present, surface flow off Western Australia is weakly to the south.

To test the hypothesis that a north-flowing west Australian current led to enhanced coastal upwelling and primary productivity off western Australia at the LGM, we present data from a set of gravity cores from the Exmouth Plateau ($\approx$ 19°S, 113°E, 950 to 2250 m) and the Perth Basin ($\approx$27°S, 111°E, 2750 m). The Exmouth Plateau lies at the north end of the zone of cool LGM SST values, and our Perth Basin cores are located near the center of this zone. We determined organic carbon and $CaCO_3$ mass accumulation rates, benthic foraminiferal abundance variations, benthic foraminiferal paired-species $\Delta\delta^{13}C$ values, and the accumulation rate of authigenic uranium. LGM organic carbon accumulation rates were higher than Holocene values but the increase was small (less than a factor of 1.5). The authigenic uranium content and benthic foraminiferal abundances are both higher in glacial sediments. These data are consistent with higher surface ocean productivity during the glacial, but we cannot yet relate these proxies to carbon flux quantitatively. Paleoproductivity estimates based on paired-species $\delta^{13}C$ differences have a large uncertainty at the low carbon fluxes observed in this region, but the $\Delta\delta^{13}C$ values from our cores show little Glacial-Holocene change. Together, these records suggest that the Glacial productivity off Western Australia was elevated relative to Holocene values, but they provide no evidence of strong upwelling similar to that observed in the modern ocean off the western coasts of southern Africa and South America.

NITROGEN ISOTOPE FRACTIONATION IN THE MODERN OCEAN: IMPLICATIONS FOR THE SEDIMENTARY RECORD

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The isotopic composition of combined nitrogen in the ocean is affected by the isotopic fractionation associated with a suite of biological processes including nitrogen fixation, denitrification, the assimilation of inorganic nitrogen by phytoplankton, and a variety of food web interactions. Although the global balance between oceanic nitrogen fixation and denitrification appears to be the primary determinant of the mean $\delta^{15}N$ of marine nitrogen, the fractionation associated with primary production and trophic processes may exert a strong influence on the $\delta^{15}N$ of organic matter incorporated into marine sediments. For example, the $\delta^{15}N$ of phytoplankton is dependent on the isotopic signature of the available pool of inorganic nitrogen, which is typically dominated by NO_3^-. In stratified waters, however, zooplankton excretion of NH_4^+ may support a significant fraction of the phytoplankton nitrogen demand, leading to a mean phytoplankton $\delta^{15}N$ significantly different form that of the NO_3^- available in deep water. Although the physiology of isotopic fractionation by animals is not understood in detail, animals form a wide variety of ecosystems are enriched in ^{15}N by roughly 3.5‰ relative to their food. One consequence of this trophic effect is that food webs act as a sort of isotopic fliter between the primary producers and the forms of nitrogen most likely to be preserved in sediments. That is, the transport of organic matter to the deep ocean may be accompanied by significant shifts in $\delta^{15}N$ since the relatively large, rapidly sinking particles that constitute a major fraction of the vertical flux of organic matter (e.g., fecal pellets and crustacean exuvia) typically have a $\delta^{15}N$ markedly different form that of the primary producers. Although this filtering complicates the interpretation of nitrogen isotope data, it may also lead to the preservation of a food web signature in the sedimentary record. In combination with measurements of the $\delta^{15}N$ of bulk sedimentary organic nitrogen, isotopic analysis of biomolecules such as chlorphyll *a*, pheopigments, and chitin may ultimately provide a powerful tool for studying the biological processing involved in the transport of organic matter from the surface ocean to the deep sea.

THE EFFECT OF CHANGING CONTINENTAL WEATHERING RATES ON ATMOSPHERIC CO_2 OVER GLACIAL-TO-INTERGLACIAL TIME SCALES

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A nine-box model of the ocean-atmosphere subsystem of the global carbon cycle has been developed to study the effects of some possible scenarios of the last glacial-interglacial transition. It has been adjusted to reproduce the distributions of total dissolved inorganic carbon, total alkalinity, phosphate, $\delta^{13}C$ and the $\Delta^{14}C$ of the modern ocean and the partial pressure of atmospheric CO_2. A simple sedimentation scheme at 20 different depth levels drives carbonate deposition and dissolution as a function of the depth of the (dynamic) calcite lysocline in each of the three ocean basins considered (Atlantic, Antarctic and Indo-Pacific). Furthermore, we have added a simple strontium cycle to take advantage of the recently published $^{87}Sr/^{86}Sr$ data for the last 300,000 years (Dia et al., Nature, *356*, 786-788, 1992). These data are used to construct different scenarios of changes of the continental weathering rates of silicate and carbonate rocks. They indicate that the related carbon and alkalinity fluxes entering the ocean-atmosphere system may have been substantially higher during glacial times than today. These variations may explain part of the observed changes of the partial pressure of atmospheric CO_2 between glacial and interglacial periods.

ATMOSPHERIC ENVIRONMENT OVER THE LAST CLIMATIC CYCLE DEDUCED FROM ICE CORE RECORDS

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Ice cores provide the opportunity of access to parameters which are related to climate or environmental changes. Most of these parameters are of regional or even global significance. There are now several ice cores from Greenland and Antarctic ice which penetrate into the ice which was formed during the last ice age and one (at Vostok in Antarctica) covering the entire last climatic cycle.

The Last Glacial Maximum (around 20 Ky BP) is characterized by much colder conditions, reduced precipitations, lower atmospheric CO_2 and CH_4 concentrations.

A large increase of continental and marine aerosol is observed and interpreted by a more vigorous atmospheric circulation associated with continental aridity, shelve and sea ice extent.

The Vostok record of temperature and CO_2 are well-correlated and show large 100 Ka signal, as well as shorter periodicities characteristic of the earth orbital parameter. These features suggest a fundamental link between the climatic system and the carbon cycle and stress the role of radiative active gas in climatic changes.

Major changes observed in the dust record are also suggestive of global significance and confirm the existence of a link with earth's orbital parameters. The use of a major dust event in Vostok ice as stratigraphic marker to compare timing with climatic record from deep-sea sediment was proposed. The lack of dust records in the open Southern ocean and the possible regional variability in the continental dust production and transport limit such an approach. However, it is suggested that the Vostok and marine record are roughly in phase during glacial to interglacial terminations.

VARIATIONS IN SEDIMENTARY ORGANIC $\delta^{13}C$ AS A PROXY FOR GLACIAL/ INTERGLACIAL CHANGES IN OCEAN CO_2 SUPPLY AND DEMAND

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Theoretical considerations, experimental results, and ocean observations indicate that the $\delta^{13}C$ of marine plankton and their organic sedimentary remains can be used as a proxy for ambient molecular CO_2 concentration, [CO_2(aq)], in ocean surface waters. When combined with measurements/estimates of surface water temperature, ocean and atmospheric pCO_2 can be reconstructed, the latter assuming local pCO_2 equilibrium between ocean and atmosphere. An important line of evidence for this approach can be found in the present ocean. A recent compilation of *in situ* ocean data (N=296) shows that about 90% of the $\delta^{13}C$ variation within bulk plankton or suspended particulate organic matter (POM) can be explained by a simple negative linear response to ambient [CO_2(aq)], with the slope of the best-fit line = -0.6 (+-0.01‰ mM^{-1}). Positive effects on plankton $\delta^{13}C$ imparted by increasing phytoplankton CO_2 demand may be the principle source of the residual isotopic variability encountered. When plankton or POM $\delta^{13}C$ is specified, the standard error of the estimate of [CO_2(aq)] with this model is <+-2.0 mM. This translates into a temperature-sensitive average ocean/atmospheric pCO_2 estimation error of about +- 50 matms when sea surface temperature and $\delta^{13}C$ are provided. Within such error, there is relatively little difference among the various proposed linear, logarithmic, and inverse models of $\delta^{13}C$ vs [CO_2(aq)] when they are fitted to this modern-ocean data set. In contrast, a nonlinear inverse relationship that can be influenced by phytoplankton CO_2 demand is theoretically expected.

When applied to the sedimentary organic $\delta^{13}C$ record, such models predict that the approximate 80 µatms increase in atmospheric CO_2 between the last glacial/interglacial transition (as documented by ice core analyses) should have resulted in a 2-3 ‰ decrease in plankton $\delta^{13}C$. Such changes are generally evident in the Holocene/ Pleistocene sediment core profiles of organic $\delta^{13}C$ thus far reported. However, some geographic differences in past plankton isotopic response are present and expected due to i) regional non-equilibrium between ocean and atmosphere [CO_2], and ii) changes in phytoplankton CO_2 demand (productivity). Isolation and analysis of phytoplankton-specific organic compounds from the sedimentary record may improve isotopic reconstruction of past plankton communities and associated CO_2 abundances once the empirical relationships among biomarker $\delta^{13}C$, phytoplankton $\delta^{13}C$, and CO_2 concentration have been established. Further research is needed to better determine the applicability and limitations of estimating paleo-CO_2 concentrations from organic $\delta^{13}C$ measurements within the sedimentary record.

CARBON BURIAL UNDER COASTAL UPWELLING ZONES DURING GLACIALS: PROCESSES AND PREDICTIONS AS SEEN FROM A NUMERICAL MODEL

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Ocean margins appear to play a major role in the earth's carbon cycle, based on observations that the flux rates of carbon through this system and rate of sequestration of carbon in sediments are vastly greater than those of the open ocean. However, the relative importance of the many possible forcing factors and their interactions is unknown. Further, it is not known to what degree this system reacts with other carbon systems, e.g., the role that ocean margins play in determining atmospheric CO_2. Although low latitude upwelling areas are (today) net outgassers, a decrease in this outgassing may contribute significantly toward the glacial/interglacial changes in atmospheric pCO_2. There are few dynamic models of the carbon system along coastal margins, particularly that can be applied to the geologic past, and global scale OGCM carbon models lack the resolution necessary to simulate the ultra-productive eastern ocean margins.

I have constructed a latitudinally-oriented 2-dimensional carbon-cycle model to address some of these issues. Changes in carbon cycling off continental margins is a function of several quasi-independent processes, including ocean upwelling, the chemistry of upwelled water, and input of terrestrially-derived nutrients and sediments (including organic carbon). In this presentation, I will concentrate upon simulation of the ocean upwelling system. The model uses primarily parameters and tracer fields that can be estimated from paleoproxy data and it can be easily applied to any coastline so long as reasonable boundary conditions can be estimated (bottom topography, wind strength, and nutrient budgets). I will show the sensitivity of modeled organic carbon burial, CO_2 outgassing, and carbonate $\delta^{13}C$ values to variations in variables such as bottom topography, wind stress, surface temperature, aridity (and thus flux of fluvial and eolian sediments), upwelled water mass nutrient concentrations, and seasonality, all parameters that may be expected to change with glacial conditions. I will also explore the implications of competing hypotheses regarding the mechanisms by which organic carbon is preserved in bottom sediments.

The carbon model is coupled to a vectorial circulation model by E. Maier-Reimer (MPI Meteorologie, Hamburg). Tracers include PO_4, some combination of biomass and detrital POM, DOM, ΣCO_2, and alkalinity. Modeled production is a function of PO_4, DOM, and light; organic flux sinks, is partly remineralized, and readvected. Carbonate and opal sedimentation are functions of productivity, and siliciclastic sedimentation depends on wind-speed, distance from shore, and regional aridity. Organic carbon burial is a semi-empirical function of productivity, depth, and total sedimentation, derived from Eastern Atlantic core data. Sediment transport is proportional to the depth gradient. The model runs are based on an annually stationary field (with varying degrees of seasonality) derived from several years of model integration (Δt=3h). The model was initially tuned to and tested using data from modern records from Meteor and JOINT-1 cruises off northwest Africa, for which fields within 250 km of shore are fairly well simulated; I will present simulations for the LGM for northwest Africa, southwest Africa, Peru, Panama, and the Western United States.

In regions of low-to-mid latitude upwelling, glacial periods observed generally higher trade wind speeds, aridity, and seasonality. The model confirms that — other conditions being equal — these factors operate in the same direction to create higher phytoplankton-derived export of organic carbon to the deep sea. Sea level drops alone increase intensity of upwelling to the sea surface at the shelf-slope break, through the decrease of diffusion of upwelled waters onto the shelf. Primary productivity and organic carbon burial along the coast increase nonlinearly with increases in wind speed (and consequent advection) and this nonlinearity is magnified by amplified seasonality. Further, increased wind speeds enhance organic carbon burial off arid areas such as northwest Africa through increased eolian sedimentation. However, regional variations in climate, nutrient budgets, and terrestrial fluxes may significantly modify or even reverse the sign of glacial changes in local carbon budgets.

THE RELATION BETWEEN DISSOLVED CADMIUM AND PHOSPHATE IN MODERN SEAWATER WITH IMPLICATIONS FOR THE USE OF CADMIUM AS PALEONUTRIENT TRACER

P.M. Saager (Dept. of Earth Sciences, Amsterdam,The Netherlands), H. J.W de Baar, and R.N. Nolting

The vertical distributions of dissolved Cd and PO_4 in today's oceans are very similar. The mechanism behind this relation has not yet been unequivocally assessed. The relationship has been quantified in order to enable the use of Cd as paleonutrient tracer. The ensuing equation was largely based on a compilation of data from the North Atlantic and North Pacific oceans.

Data are now available for most of the world's oceans. It appears that the traditional approach of property-property plots throughout the water column obscures interesting trends. Also, as the oceans are mainly mixed horizontally one compares water masses with totally different physical and bio-chemical properties operating on different time scales. To a first approximation the aforementioned relationship should be separated into surface waters, waters from the permanent thermocline and the thermohaline-driven deep waters.

In surface waters the relation is generally poor. Cd/P-*ratios* tend to increase with increasing Cd and P concentrations. In the thermocline the relation is strong and most likely mechanistic. In deep waters Cd and P behave almost conservatively and the relation is dominated by mixing of different water masses. Probably as much as 75% of Atlantic and 40-50% of Pacific deep water concentration is preformed. In deep-water-source-areas the relation between Cd and PO_4 is poor. For deep waters the relationship is thus not entirely mechanistic and cannot be interpreted without a quantitative understanding of the coupling between both tracers in surface waters. The circulation of the oceans largely determines the Cd-PO_4-relationship and ocean circulation has likely dramatically changed through time. Therefore, if anything, the Cd-PO_4 relationship is not likely to have remained constant through time.

Numerical simulation models should provide more insight into the relative contribution of mechanistic and conservative processes to this relationship, as well as between other trace metals and nutrients.

PRODUCTIVITY IN THE NORTH ATLANTIC AND NORTH PACIFIC DURING THE LGM: EVIDENCE FROM DIATOMS

C. Sancetta (National Science Foundation, Washington, USA)

Modern (core-top) and Holocene diatom assemblages north of 45°N in the Pacific and Atlantic oceans are quite different, reflecting the very different conditions of primary production. The North Atlantic is characterized by a large spring bloom and relatively low summer production limited by major nutrients while the North Pacific has no bloom and is not major-nutrient limited; it has been suggested that trace elements such as iron control the nature of primary production in this region. CZCS and *in situ* measurements indicate that biomass/productivity in the North Pacific is roughly half that of the North Atlantic.

In contrast, assemblages representing the LGM in both oceans are very similar, based on one core in the North Atlantic (ODP 609) and several in the North Pacific. The modern analog assemblages are found in the Sea of Okhotsk and Baffin Bay, both regions of very high levels of primary production not limited by nutrients nor, during the summer, by light. These regions are also characterized by the seasonal presence of sea ice and, in Baffin Bay, icebergs. The glacial diatom assemblage consistently occurs in association with high IRD. I infer that the presence of ice-enhanced primary production in both oceans by physical mixing and stratification processes and/or by release of major and trace nutrients during melting. If levels of production equal to those of the coastal zone were maintained in the open ocean, primary production in the glacial North Atlantic was at least as high as it is today, and in the North Pacific a factor of two higher. The occurrence of a spring bloom persisted in the North Atlantic throughout the last 20,000 years.

VARIATIONS OF pCO_2 IN EQUATORIAL SURFACE WATER OVER THE LAST 330,000 YEARS: THE $\delta^{13}C$ RECORD OF ORGANIC CARBON

M. Sarnthein (Geologisch-Paläontologisches Institut, Kiel, Germany), L. Wester-hausen, U. Struck, and H. Erlenkeuser

Based on the $\delta^{13}C$ record of marine organic sediments ('Meteor' core 16772) and the rationale of Rau et al. (1989), we reconstructed the variations in CO_2 partial pressure (pCO_2) in surface waters of the East Atlantic equatorial upwelling zone for the last 330,000 years. To estimate the initial $\delta^{13}C_{organic}$ values of the plankton, the $\delta^{13}C$ values of organic matter ($\delta^{13}C_{organic}$) were corrected i) for past variations in sea surface temperature, using U^{k}_{37} proxydata, ii) for variations in the $\delta^{13}C$ composition of dissolved inorganic carbon in the surface water, using $\delta^{13}C$ values of both *G. ruber and sacculifer*, and iii) for an isotopic fractionation along with the degradation of organic matter in the water column and in the surface sediment.

The calculated paleo-pCO_2 levels in the surface water are centered generally near the bandwith of modern local pCO_2 data, on the average exceeding the pre-industrial atmospheric pCO_2 level (280 ppmv) by about 120 ppmv, except for values of less than 300 ppmv, which occured during cold isotopic events 6.3, 6.5, (7.4), and 8.4. In harmony with other recent studies in the Pacific and the Mediterranean, the reconstructed pCO_2 variations by and large parallel the atmospheric pCO_2 record as depicted in the 140,000-year VOSTOK ice-core record. The disequilibrium between global atmospheric pCO_2 and the local pCO_2 in the surface water may be linked to the ongoing CO_2 release from upwelled subsurface water. The assimilation of CO_2 by primary productivity of phytoplankton counteracts the CO_2 supply by upwelling and hence reduces the disequilibrium; this is confirmed by a positive correlation between estimated paleoproductivity and the reconstructed paleo-pCO_2.

LATE QUATERNARY pCO_2 VARIATIONS IN THE ANGOLA CURRENT: EVIDENCE FROM ORGANIC CARBON $\delta^{13}C$ AND ALKENONE TEMPERATURES

R. Schneider (Fachbereich Geowissenschaften, Bremen, Germany), P.J. Müller, and G. Ruhland

The $\delta^{13}C$ record of organic carbon in Late Quaternary sediments of the Eastern Angola Basin (core GeoB 1016-3, 11°46.2'S, 3411 m) shows a pronounced cyclicity with high values (-18 to -20‰) in glacial isotopic stages 2 to 4 and stage 6, and lower values (-20 to -21.2‰) in interglacial stages 1 and 5. Sea-surface temperatures, derived from the alkenone U^{k}_{37} index, vary in the opposite sense, ranging from 20-22°C in glacial stages 2 to 4 up to 24-26°C in the interglacial stages. The inverse relationship between $\delta^{13}C_{org}$ and SST values suggests that the isotopic variations are not due to temperature-dependent isotopic fractionation during photosynthesis, which would lead to an increase of $\delta^{13}C_{org}$ values with increasing temperature. Relationships between sedimentary $\delta^{13}C_{org}$ and C/N ratios indicate that different proportions of marine and terrigenous organic matter can also be ruled out as a cause for the $\delta^{13}C_{org}$ variability. We therefore conclude that changes in surface water CO_2 concentrations were responsible for the observed glacial to interglacial isotopic variations.

Using the relationships between planktonic $\delta^{13}C_{org}$ and dissolved $CO_2(aq)$ derived by POPP et al. (1989) and RAU et al. (1990) we estimate that surface water pCO_2 of the Angola Current (AC) was consistently higher than the Vostok atmospheric CO_2 record of the last 160,000 years by an average of about 75 µatm. This indicates that the AC generally acted as source region for atmospheric CO_2 during this period, which is consistent with the modern situation. However, both records show a high degree of co-variation, the glacial to interglacial pCO_2 increase at terminations I and II being 70-90 µatm, for example. It is suggested that the AC was a weaker CO_2 source in glacial periods due to lower sea-surface temperatures and higher biological productivity. This may in general be the contribution of equatorial current systems to the glacial atmospheric CO_2drawdown.

LATE QUATERNARY DEEP-SEA BENTHIC FORAMINIFERS AND BOTTOM-WATER MASSES: AN UPDATE

D. Schnitker (University of Maine, Orono, U.S.A.)

Benthic foraminifers are an abundant and easily preserved component of the deep-sea meiofauna. Early work demonstrated that the fauna is nearly cosmopolitan. Subsequent work showed that, at least on regional scales, the benthic foraminiferal faunas were very strongly structured. Initially, it was demonstrated that in the North and South Atlantic the distribution of benthic assemblages followed the distribution of named "water masses," which led to the expectation that fossil benthic foraminifers from sediment cores would allow a reconstruction of past deep-water circulation patterns. Controversy arose when it was demonstrated that in other areas the faunal composition was strongly correlated with the productivity of the overlying surface waters.

Ecological principles predict such results: the benthic meiofauna responds to the integral of the deep environment and it is the limiting or overwhelming influence that determines the success or failure of individual species and thus the composition of the fauna. Analysis of all available data clearly indicates that benthic foraminifers are unequivocal indicators of productivity in areas where productivity is high. In areas of low or very uniform productivity the composition of the benthic faunal clearly carries the imprint of deep water mass structure as the dominant feature.

Faunal sequences from late Quaternary cores from the Atlantic and Pacific oceans show very strong differentiations. Not only is the glacial/postglacial transition shown, but also much superimposed fine structure. Faunal composition is apparently much more sensitive to deep-water environmental change than are geochemical indicators. The faunal composition allows at least some appreciation of the cause for the major changes, but not yet a quantitative differentiation between productivity or water mass changes. If, however, an independent assessment of productivity change is available, then the benthic foraminiferal faunas are exquisite indicators of changes in deep water circulation.

QUATERNARY PRODUCTION CHANGES IN THE EASTERN EQUATORIAL PACIFIC AND OFF PERU: ONE KEY TO UNDERSTANDING ATMOSPHERIC CO_2 CHANGES?

H. Schrader (Dept. of Geology, Bergen, Norway)

Changes in the magnitude of biological activity in coastal upwelling areas of the eastern boundary current systems (the Californian, Peruvian, Namibian and North West African coastal areas) and oceanic upwelling areas (the eastern Equatorial Pacific and the eastern Equatorial Atlantic) have fundamental influences on the transfer of atmospheric carbon via biological fixation and storage in underlying organic, carbon-rich sediments. Two time series of primary production from ODP Sites 681 (off Peru) and 677 (off Ecuador) are introduced.

The transfer function technique (relating marine planktonic diatom assemblages in surface sediments to mapped primary production) was used to calculate primary production variations over hole ODP Leg 112, Site 681A (off central Peru) and over hole ODP Leg 111, Site 677 A&B (off Ecuador) over the last 400 kyr. Primary production off central Peru and off Ecuador was enhanced during peak glaciations and it was decreased during peak interglacials; but low and high production periods also occurred in both glacials and interglacials.

The close resemblance of the primary production curve off Peru to the atmospheric CO_2 Vostok record suggests a relationship between the Peruvian neritic biological pump and the Ecuadorian oceanic pump and atmospheric pCO_2.

BARIUM, OPAL AND ORGANIC CARBON RECORDS FROM THE SOUTHERN OCEAN: POSSIBLE CONSTRAINTS ON THE GLACIAL PRODUCTIVITY HYPOTHESIS

G. Shimmield (Univ. of Edinburgh, Scotland, UK), S. Derrick, A. Mackensen, and C. Pudsey

Deep-sea sediments from the Southern Ocean record palaeoceanographic changes relating to biological productivity, terrigenous input from the Antarctic continent and adjacent islands, and the influence of deep bottom water currents. The unique oceanographic setting of the Southern Ocean and strong upwelling associated with Circumpolar Deep Water and the Antarctic Polar Front (APF) result in high surface water nutrient concentrations and associated productivity. Many previous workers have studied and mapped the sedimentary "diatom ooze belt" which lies just to the south of the APF (particularly in the Atlantic and Indian Ocean sectors) and have shown that the sediments can record locally biogenic opal concentrations of up to 75%. Associated with opal are large quantities of barium produced biogenically within the water column. Farther south the abundance of siliceous organisms decreases substantially, probably due to the combined effects of dissolution and dilution by terrigenous components. Over most of the Southern Ocean there is extremely poor preservation of carbonate tests of marine organisms due to the shallow lysocline (≈500m in the vicinity of the Scotia Arc). The paucity of a calcareous fauna has severely hampered studies of palaeoceanographic change south of the APF, and in particular, estimates of biogenic opal and organic carbon accumulation rates. The importance of constraining silica and carbon budgets in the Southern Ocean is further supported by studies of past atmospheric CO_2 levels that have suggested that increased ocean productivity during glacial episodes has had an important impact on global climate. However, most recent studies have pointed to a reduction in productivity south of the APF during glacial episodes. In this study we have concentrated on a transect from the APF, through the Scotia Arc, across the Weddell Sea to Cap Norwegian on the Antarctic continental margin. This allows the study of both the position of the APF, and intensity of bottom water flow resulting from formation of Antarctic Bottom Water (AABW) in the Weddell Sea, to be studied through time. Of key importance is the establishment of a satisfactory chronology and correlation between cores for the estimation of palaeoceanographic fluxes.

Five piston cores, collected by the BAS and AWI, have been studied using a variety of inorganic geochemical techniques (XRF, wet chemistry for opal, elemental analysis for carbon).. These BAS cores are from water depths between 3300-3550m and are from the 40°-45°W meridian at approximate latitudes 52°, 56°, 61° and 62°S (cores 36, 29, 27 and 41, respectively). The present day APF is at ~52°S at this longitude, although the hydrography is complicated by bathymetry. This transect is located close to the axis of AABW outflow from the Weddell Sea through the Scotia Arc. The final core, 1506, located off Cap Norwegian was collected by AWI and lies within a small biogenic carbonate-rich province, allowing stable isotope stratigraphy to be developed.

Using isotope stratigraphy from 1506, the downcore analysis (over 4.5m) of barium records some 360 ky of biogenic productivity. The BAS cores also contain striking barium records which have allowed an accurate correlation between the core sites to be developed. Ba is clearly enriched in Holocene and Stage 5 sediments. This is the first time, to our knowledge, that such high-resolution stratigraphy in the deep Weddell and Scotia Seas south of the APF has been possible. Sediment accumulation rates are at a minimum from Stage 5 through to 24 ky BP (5.4, 2.3, 4.1, 5.7, 1.7 cm/ky in the core sequence above); between 24 and 18ky rapid ice melt leads to elevated accumulation rates (20.0, 20.2, 15.0, 12.7, 3.6). Since 12ky BP the rates have dropped by at least half. Highest biogenic opal abundance is recorded close to the present APF (19.5 wt.%), decreasing to 2.3% at core 41. Organic carbon abundance is relatively constant at about 1.5%. In this paper, the palaeoceanographic significance of proxy-indicators (Ba, opal and C_{org}) are compared and contrasted using the Ba time-scale. In addition, Ti/Al and Zr/Rb ratios are used to inter bottomwater velocities over the last 130 ky. Manganese and molybdenum concentrations attest to important changes in bottom water redox-state, and/or removal (scavenging) from the overlying water column. These combined tracers indicate that the deep Weddell Sea/Scotia Sea is far from being a scoured conduit for AABW and that geochemical tracers can provide reliable estimates of chronology and accumulation rate for improving our understanding of palaeoproductivity in polar environments through glacial-interglacial episodes.

QUANTITATIVE ASSESSMENT FOR PARTICLE FLUXES: A LINKAGE BETWEEN MODERN OCEANS AND PALEOENVIRONMENTS

K. Takahashi (Hokkaido Tokai University, Sapporo, Japan and Woods Hole Oceanographic Institution, Woods Hole, USA)

Particle fluxes using sediment traps have been seriously studied for various microfossil groups in the past decade. We have accumulated substantial amounts of information pertinent to properly interpret the past environments. Characterization of productivity signals in present-day particle fluxes can be significant when it is applied to calculate past productivity levels. A match between fidelity productivity signal and good preservation in a given species is a prerequisite for such a conversion Since the majority of biogenic silica production is lost due to dissolution mainly at the sea floor and only a minute fraction can be preserved in the fossil record, such a task cannot always be fulfilled. However, when the productivity signal is in solution-resistant taxa such a conversion can materialize. *Denticulopsis seminae*, a pennate diatom taxon, widely occurs in the high latitude North Pacific. It is clearly a productivity and dominant diatom species with relatively good preservation in the fossil record at least in the northeastern Pacific. Quantitative interpretation of paleoproductivity levels will be demonstrated using the flux information of the productivity tracer species.

DISTRIBUTION OF $\delta^{13}C_{\Sigma CO2}$ AND TRACE METALS IN THE OCEAN: IMPLICATIONS FOR BENTHIC $\delta^{13}C$ AND Cd/Ca RECORDS AS PROXIES FOR INTERMEDIATE-DEPTH NUTRIENT CYCLING AND THE ATMOSPHERE'S PALEOCHEMISTRY

R. Zahn (GEOMAR, Kiel, Germany) and R. Keir

Continuous accumulation of $^{12}C_{\Sigma CO2}$, Cd and biologically cycled nutrients below the pycnocline stabilizes the deep-ocean (σ_θ >27.7) tracer-nutrient fields, thus leading to monotonic $\delta^{13}C_{\Sigma CO2}$-$PO_4$ and Cd-PO_4 relationships. In the upper ocean ($26.8 < \sigma_\theta < 27.7$), however, these relationships vary as a function of nutrient extraction, Cd- and $\delta^{13}C_{\Sigma CO2}$-cycling in the euphotic layer, vertical exchange, and ocean-atmosphere gas exchange. Data collected during the GEOSECS program in intermediate and deep water outcrop areas shows that PO_4 intercepts (*i.e.*, preformed PO_4) in the tracer-nutrient relationships may vary from ± 0 µmol kg^{-1} for the oligotrophic North Atlantic to >1.3 µmol kg^{-1} for the Southern Ocean. That is, while the Cd- and $\delta^{13}C_{\Sigma CO2}$ "clocks" are reset to their starting values before surface waters enter the convection-advection pathway, PO_4 concentrations may vary significantly thus resulting in marked variations of the tracer-nutrient regression slopes. Dominant factors in defining the $\Delta\delta^{13}C : \Delta PO_4$ and $\Delta Cd : \Delta PO_4$ slopes are: (1) efficiency of the marine biota to exhaust nutrients in the surface layer, (2) rate of biotic $^{12}C_{org}$- and Cd-fixation, (3) ^{12}C-distillation from the surface ocean to the atmosphere, and (4) rate and depth at which tracers and nutrients are recycled.

The effects that differential uptake of cadmium and phosphate in polar surface waters may have on their relative distribution throughout the ocean are illustrated with a 13-box model. In this model, the advective component of the surface water source is estuarine in Antarctic waters and anti-estuarine in the North Atlantic. Because of this, the effects of preformed Cd in each of these regions on the Cd-PO_4 pattern are very different. Decreasing the preformed Cd concentration in the North Atlantic has virtually no effect on the Cd distribution elsewhere in the ocean. By contrast, low preformed Cd in Antarctic waters produces a significant alteration to

what would otherwise be a simple linear correlation of Cd and PO_4. In this region, more efficient biological uptake of Cd distills a greater fraction of the upwelling flux into Circumpolar Deep Water and leaves Antarctic Intermediate Water depleted relative to phosphate. As a result, there is a "kink" in the deep-water trend of Cd versus PO_4, with the Indo-Pacific having greater Cd/PO_4 ratios than Atlantic deep water. Intermediate waters, especially in the southern hemisphere, are predicted to have lower Cd/PO_4 ratios than deep waters. The distribution of Cd in Circumpolar and Indo-Pacific deep waters is expected to be more uniform than PO_4, and therefore weaker N-S horizontal Cd gradients in these waters should exist.

The observed deviation of the $\delta^{13}C$ - PO_4 regressions at intermediate depths in the "eutrophic" Southern Ocean (slope ≥ 1.5, std error=0.09, n=29) from the trend observed in the "oligotrophic" North Atlantic (slope ≤ 1.0, std error=0.09, n=83) suggests importance of air-sea exchange perhaps combined with varying rates of carbonate dissolution which adds to the ΣCO_2 pool and tends to steepen the slope at the high-nutrient end of the ocean $\Delta\delta^{13}C : \Delta PO_4$ distribution. Thus even though the mechanics that link $\delta^{13}C$ and Cd to PO_4 are different, in high-nutrient regimes both tracers show similar deviations from the mean-ocean tracer-nutrient relation in a way that they tend to underestimate nutrient concentrations. The observed variation of the $\Delta\delta^{13}C : \Delta PO_4$ and $\Delta Cd : \Delta PO_4$ relations as a function of the ocean's physical and biological regimes inevitably rises concern about the reliability of foraminiferal $\delta^{13}C$ and Cd/Ca ratios, especially at shallow-ocean core sites, as paleoceanographic proxies for reconstructing intermediate-depth nutrient levels and the atmosphere's chemistry.

Author Index

first authors only

A.E. Rathburn	P1.4
G.H. Rau	N, P1.2
A.C. Ravelo	P2.9
D. Reháková	P1.9
E. Reimnitz	P2.4
D. Reynolds	S1
D. A. Richards	P1.1
M. Richter	P1.8
S.G. Robinson	Se
U. Röhl	P1.1
A. Rosell	P1.2, P2.5
R. M. Ross	N, P2.8
F. Rostek	P1.2, P1.5
W. Ruddiman	S4
A.D. Russell	P1.3
M.M. Rutgers van der Loeff	P2.7
P.M. Saager	N, P1.2
M. Saarso	P2.5
S. Safarova	P1.4
S. Sakai	P2.8
C. Samtleben	P2.5
C. Sancetta	N, P1.2
M. Sarnthein	N, P2.1, S3
C.T. Schafer	P1.8
R.P. Scherer	P2.7
H. Schmidt	P1.6, P1.9
K.U. Schmidt	P2.2
B. Schmitz	P2.2
D.A. Schneider	P2.9
R. Schneider	N, P1.6
B. Schnetger	P1.3
D. Schnitker	N
J.C. Scholten	P2.5
H. Schrader	N, P1.9
H. Schulz	P1.6
M. Schulz	P1.8
B. Schwarz	P1.4
D. Seidov	P2.8
I. Seravkin	P2.3
N.J. Shackleton	P2.9
A. Shemesh	P1.2
G.B. Shimmield	N, P1.3
W.J. Showers	P2.1
F.J. Sierro	P2.2
E.L. Sikes	P2.7
C. Simet	P2.1
F. Sirocko	P2.8
M.B. Smith	P1.8
T. Sowers	P2.7

R.P. Speijer	P2.2
C. Spencer-Cervato	P2.2
H.J. Spero	P1.8
S. Spezzaferri	P2.2
R.F. Spielhagen	P2.4
V. Spieß	P2.7
A. Spivack	S2
R. Stein	P2.4
U. Struck	P2.5
X. Su	P1.7
J.E. Swallow	P1.5
P.K. Swart	P1.8
K. Takahashi	N, P1.9
G.Tarasov	P2.4
J. Targarona	P1.7
A. Tessema	P2.2
J. Thiede	P1.4, P2.6
E. Thomas	P2.2, P2.6
R. Thunell	P1.7
J. Thurow	S5, P2.3
R. Tiedemann	P1.6
U.F. Treppke	P1.6
E. Ufkes	P1.6
H. Ujiie	P1.7
M. Ushakova	P1.4, P2.2
A. van Geen	P1.3
B. van Os	P1.7
Tj.C.E. van Weering	Se
J.C. Varekamp	P1.1
Y.K. Vasil'chuk	P2.4
M. Veerayya	P1.5
C.Vergnaud Grazzini	P1.5
G.J.M. Versteegh	P1.7
I. Vető	P1.2
J. Villanueva	P1.2
U. von Rad	P2.3
T. Wagner	P2.5
B. Wajsprych	P2.3
S.J. Wakefield	P1.2
L. Wang	P1.4
P. Wang	P2.1
P.P.E. Weaver	Se
P. Webb	S4
M. Weber	Se
K.-Y. Wei	P1.9
M.S. Weinelt	P2.1
H. Weissert	P2.3
L.A. Welling	P1.9
P. Wells	P1.5

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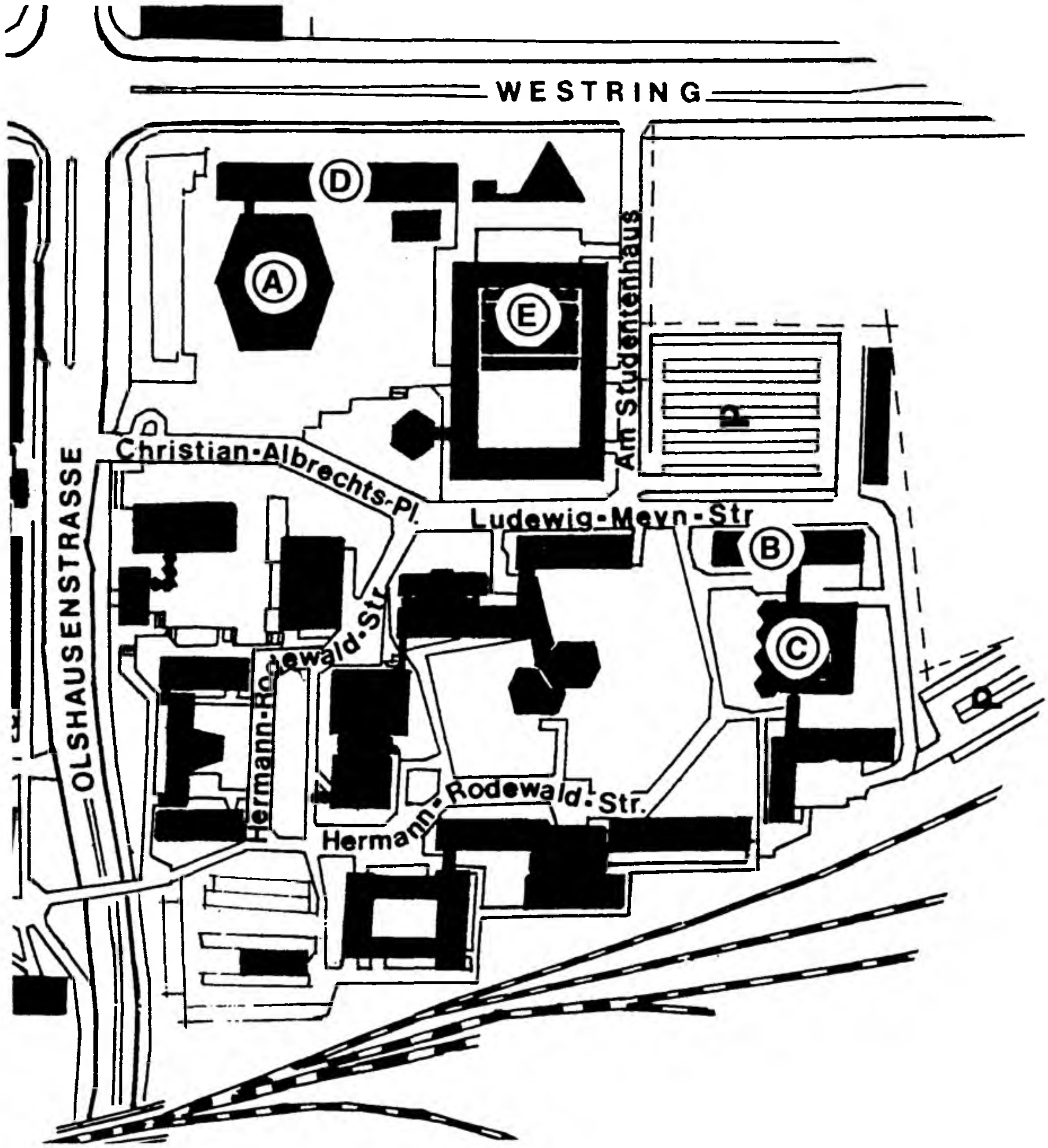

(A) Main Lecture Hall ("Audimax")

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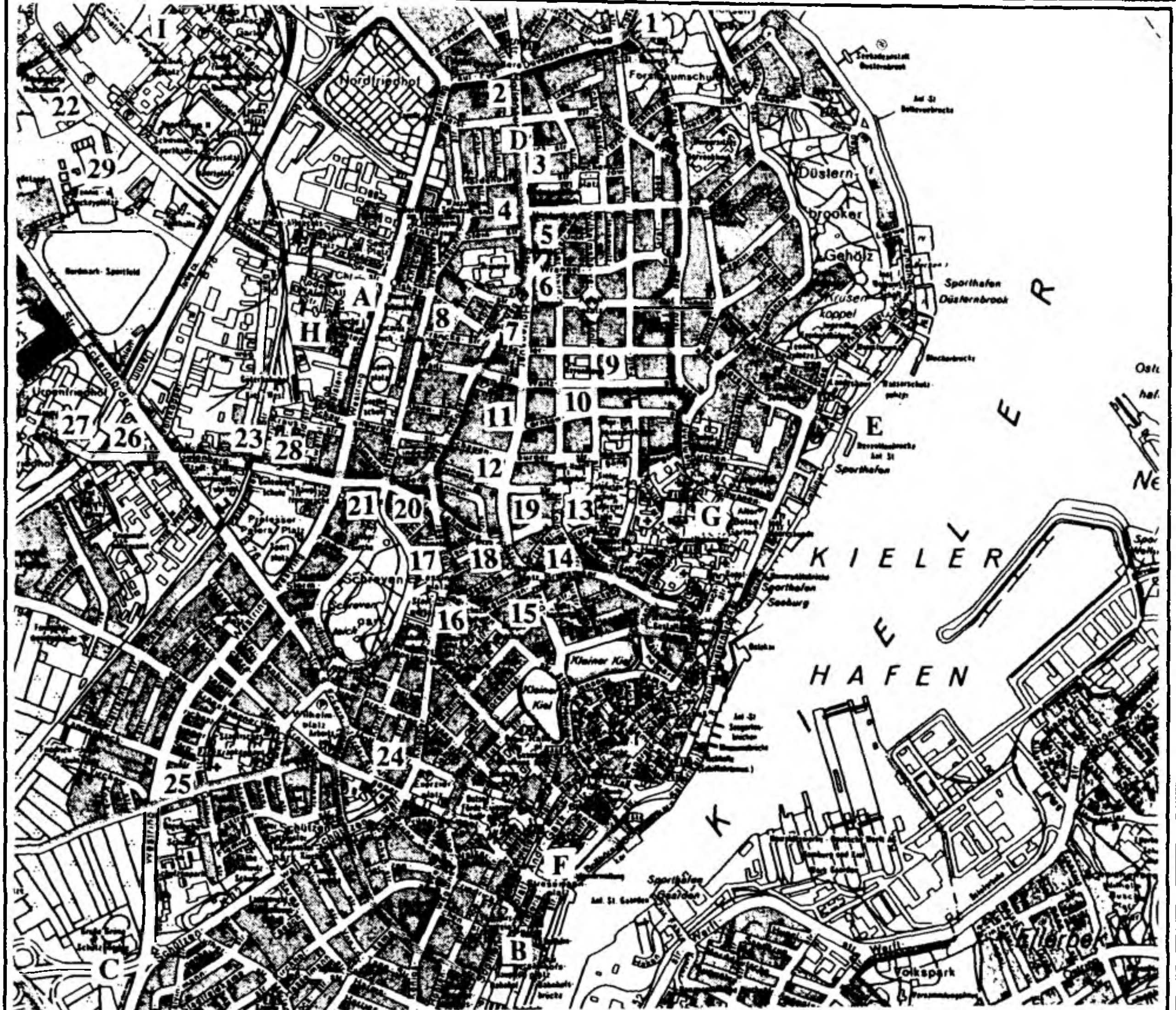
(E) Student's Restaurant ("Mensa")



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E. FERRY TO GEOMAR
F. MAIN POST OFFICE
G. UNIVERSITY CLINICS
H. GEOLOGISCH-PALÄONTOLOGISCHES INSTITUT UND MUSEUM
I. C-14 AND STABLE ISOTOPE LABORATORY

FOURTH INTERNATIONAL CONFERENCE ON PALEOCEANOGRAPHY
KIEL/GERMANY 1992

The ICP IV logo portrays:

System Earth: Interaction of continents and oceans

The city emblem of Kiel, capital of Schleswig-Holstein in northern Germany, celebrating this year its 750th anniversary of being granted the status of a city in 1242

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